The LUX Experiment

Karen Gibson *on behalf of the LUX collaboration*
TAUP 2013
Asilomar, CA
September 9, 2013

Outline

- LUX detector
  - Who - the LUX collaboration
  - What - dark matter direct detection experiment
  - Where - Sanford Underground Research Facility, Lead, SD
- Current experimental results
  - Surface commissioning (Winter 2012)
  - Underground data (Jan 2013 - present)

The LUX Collaboration

Brown

Richard Gaitskell	PI, Professor
Simon Fiorucci	Research Associate
Monica Pangilinan	Postdoc
Jeremy Chapman	Graduate Student
Carlos Hernandez Faham	Graduate Student
David Malling	Graduate Student
James Verbus	Graduate Student
Samuel Chung Chan	Graduate Student
Dongqing Huang	Graduate Student

Case Western

Thomas Shutt	PI, Professor
Dan Akerib	PI, Professor
Carmen Carmona	Postdoc
Karen Gibson	Postdoc
Adam Bradley	Graduate Student
Patrick Phelps	Graduate Student
Chang Lee	Graduate Student
Kati Pech	Graduate Student

Imperial College London

Henrique Araujo	PI, Reader
Tim Sumner	Professor
Alastair Currie	Postdoc
Adam Bailey	Graduate Student

Lawrence Berkeley + UC Berkeley

Bob Jacobsen	PI, Professor
Murdock Gilchriese	Senior Scientist
Kevin Lesko	Senior Scientist
Victor Gehman	Scientist
Mia Ihm	Graduate Student

Lawrence Livermore

Adam Bernstein	PI, Leader of Adv. Detectors Group
Dennis Carr	Mechanical Technician
Kareem Kazkaz	Staff Physicist
Peter Sorensen	Staff Physicist
John Bower	Engineer

LIP Coimbra

Isabel Lopes	PI, Professor
Jose Pinto da Cunha	Assistant Professor
Vladimir Solovov	Senior Researcher
Luiz de Viveiros	Postdoc
Alexander Lindote	Postdoc
Francisco Neves	Postdoc
Claudio Silva	Postdoc

SD School of Mines

Xinhua Bai	PI, Professor
Tyler Liebsch	Graduate Student
Doug Tiedt	Graduate Student

SDSTA

David Taylor	Project Engineer
Mark Hanhardt	Support Scientist

Texas A&M

James White	PI, Professor
Robert Webb	PI, Professor
Rachel Mannino	Graduate Student
Clement Sofka	Graduate Student

UC Davis

Mani Tripathi	PI, Professor
Bob Svoboda	Professor
Richard Lander	Professor
Britt Holbrook	Senior Engineer
John Thomson	Senior Machinist
Ray Gerhard	Electronics Engineer
Aaron Manalaysay	Postdoc
Matthew Szydagis	Postdoc
Richard Ott	Postdoc
Jeremy Mock	Graduate Student
James Morad	Graduate Student
Nick Walsh	Graduate Student
Michael Woods	Graduate Student
Sergey Uvarov	Graduate Student
Brian Lenardo	Graduate Student

UC Santa Barbara

Harry Nelson	PI, Professor
Mike Witherell	Professor
Dean White	Engineer
Susanne Kyre	Engineer
Curt Nehrkorn	Graduate Student
Scott Haselschwardt	Graduate Student

University College London

Chamkaur Ghag	PI, Lecturer
Lea Reichhart	Postdoc

Collaboration Meeting, Sanford Lab, April 2013

University of Edinburgh

Alex Murphy	PI, Reader
James Dobson	Postdoc

University of Maryland

Carter Hall	PI, Professor
Attila Dobi	Graduate Student
Richard Knoche	Graduate Student
Jon Balajthy	Graduate Student

University of Rochester

Frank Wolfs	PI, Professor
Wojtek Skutski	Senior Scientist
Eryk Druszkiewicz	Graduate Student
Mongkol Moongweluwan	Graduate Student

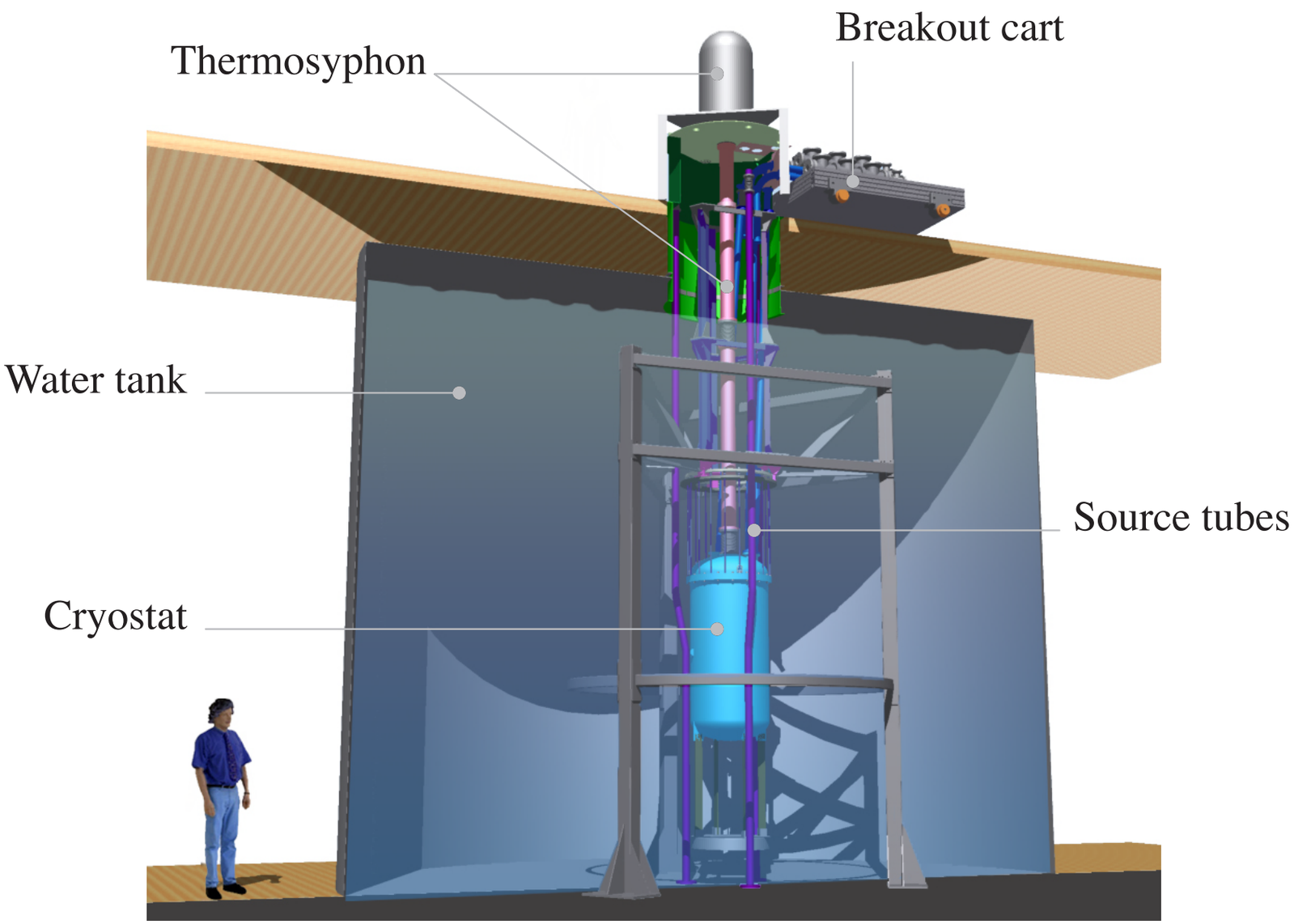
University of South Dakota

Dongming Mei	PI, Professor
Chao Zhang	Postdoc
Angela Chiller	Graduate Student
Chris Chiller	Graduate Student
Dana Byram	*Now at SDSTA

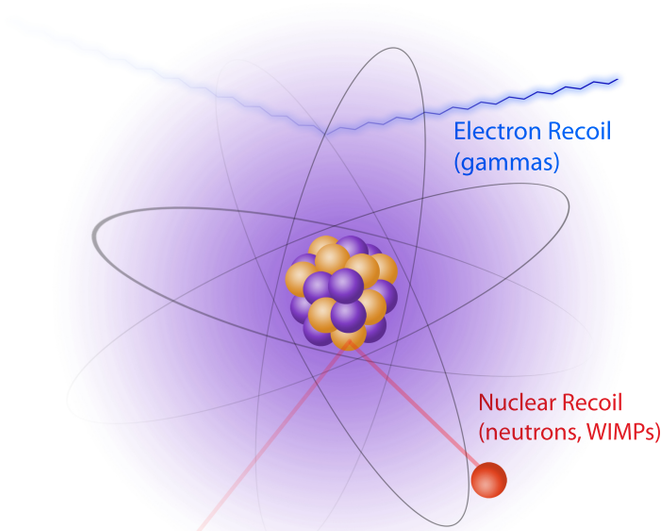
Yale

Daniel McKinsey	PI, Professor
Peter Parker	Professor
Sidney Cahn	Lecturer/Research Scientist
Ethan Bernard	Postdoc
Markus Horn	Postdoc
Blair Edwards	Postdoc
Scott Hertel	Postdoc
Kevin O'Sullivan	Postdoc
Nicole Larsen	Graduate Student
Evan Pease	Graduate Student
Brian Tennyson	Graduate Student
Ariana Hackenburg	Graduate Student
Elizabeth Boulton	Graduate Student

The LUX Detector



LUX is dark matter direct detection experiment using 350 kg liquid Xe to search for elastic scattering of WIMPs off of Xe nuclei

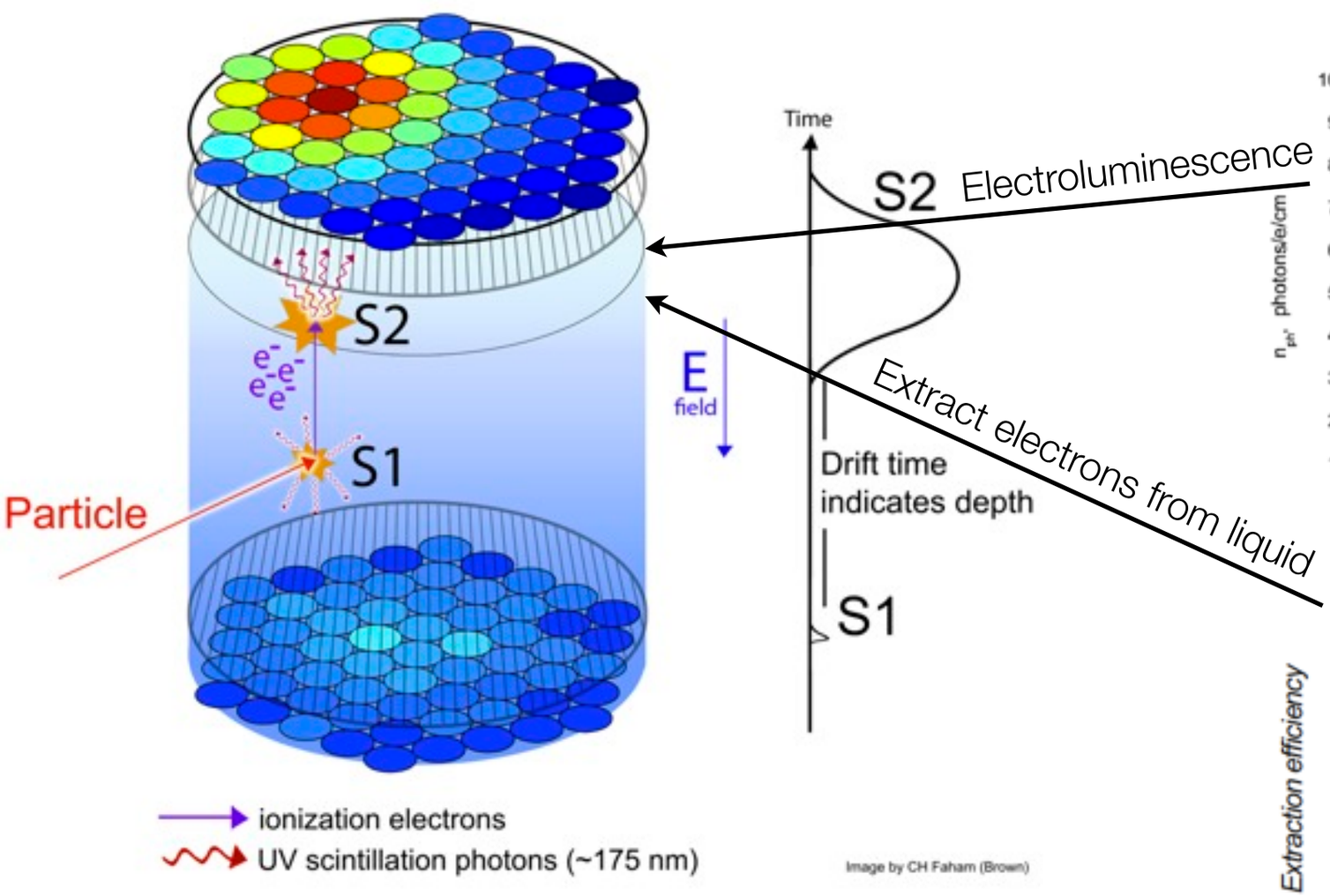


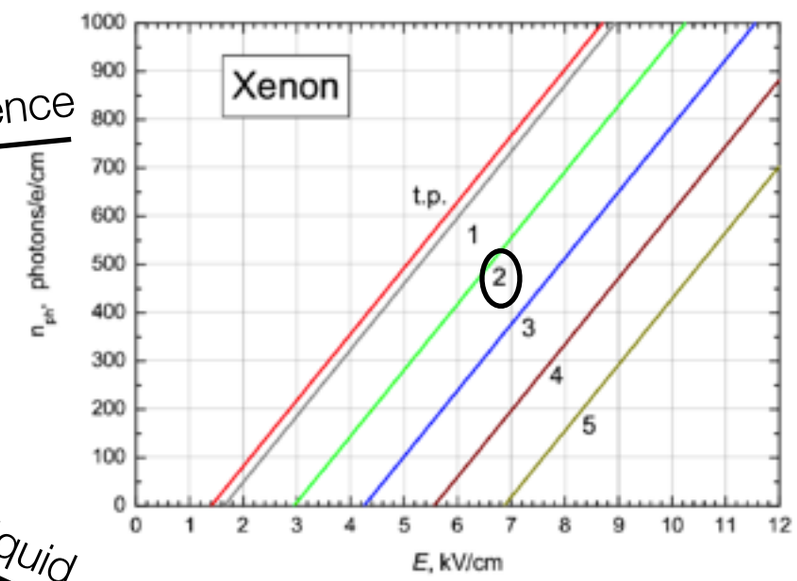
WIMP search energy region
~few keV to a few tens of keV

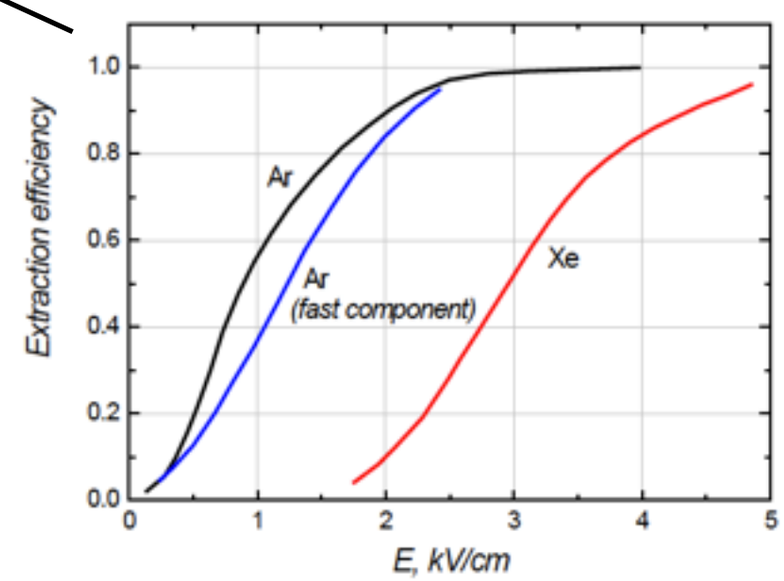
Nucl. Instrum. Meth. A 704, 111-126 (2013)

LUX - A TPC at heart

Record both primary (S1) scintillation signals and secondary (S2) scintillation due to electrons drifting away from primary event site

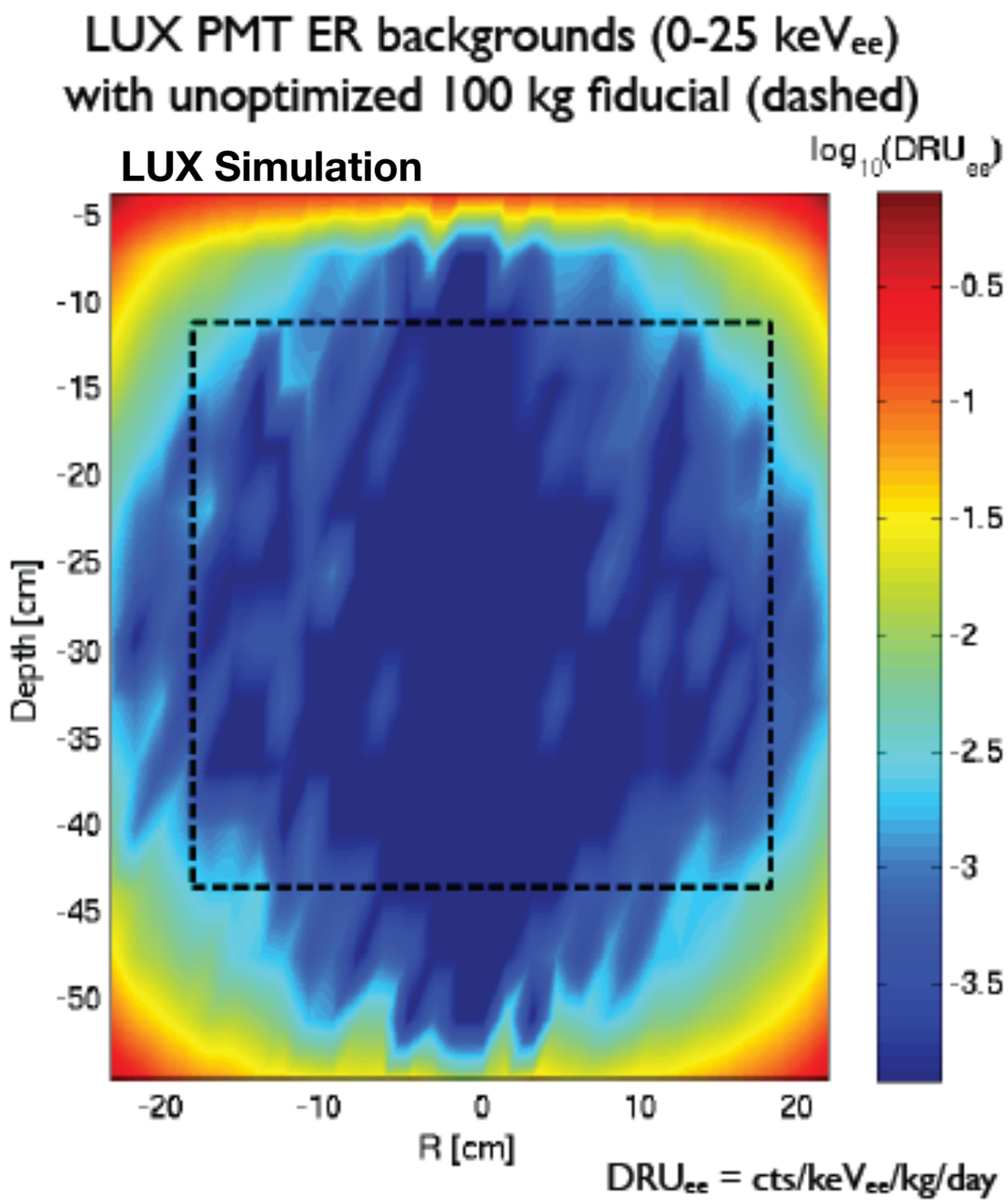


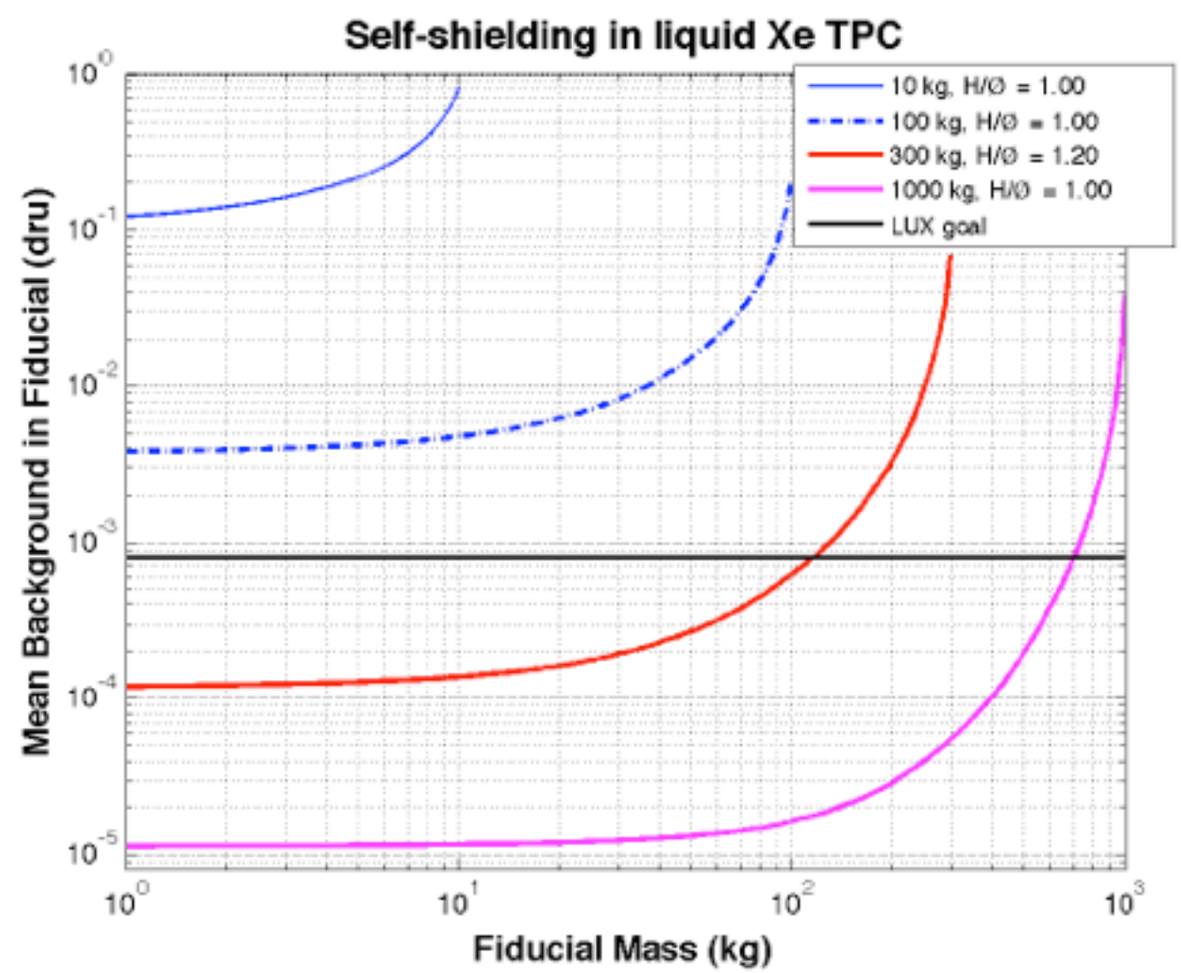




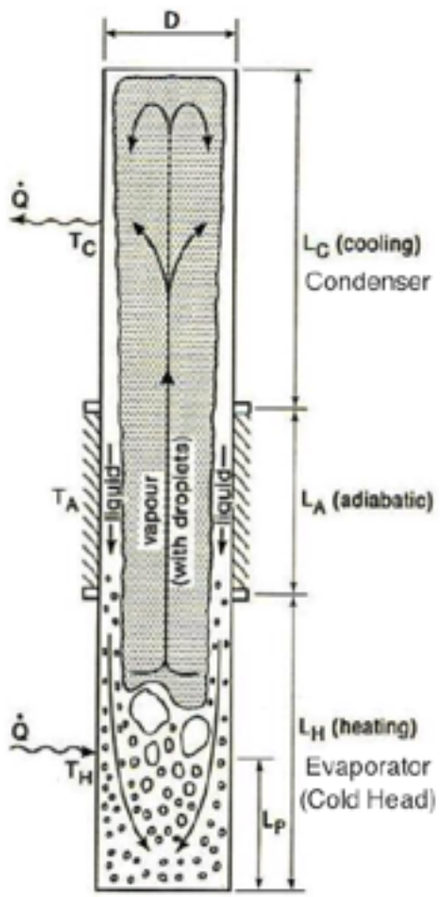
All recoils in Xe produce charge & light
- ratio of charge to light gives discrimination against backgrounds

Self-shielding of LXe reduces backgrounds

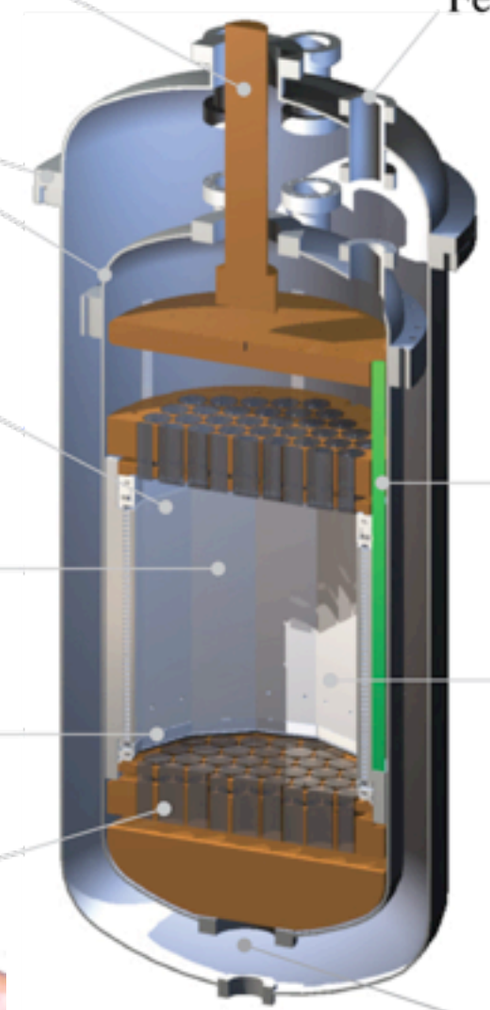




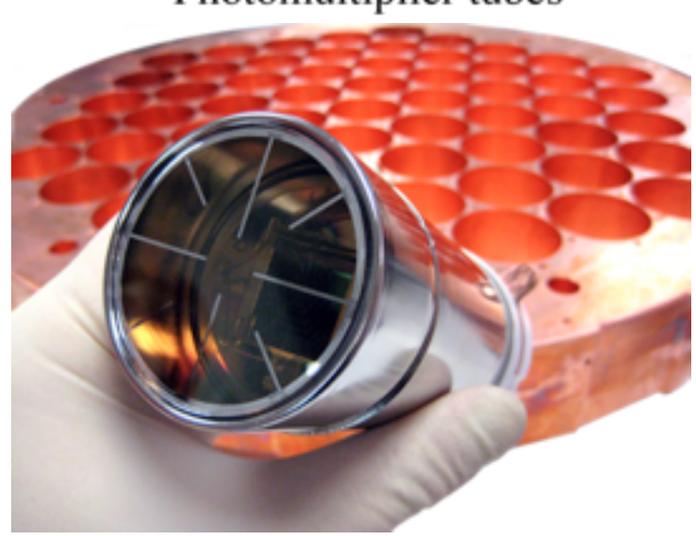
LUX Cryostat



Use thermosyphons for efficient, passive cooling

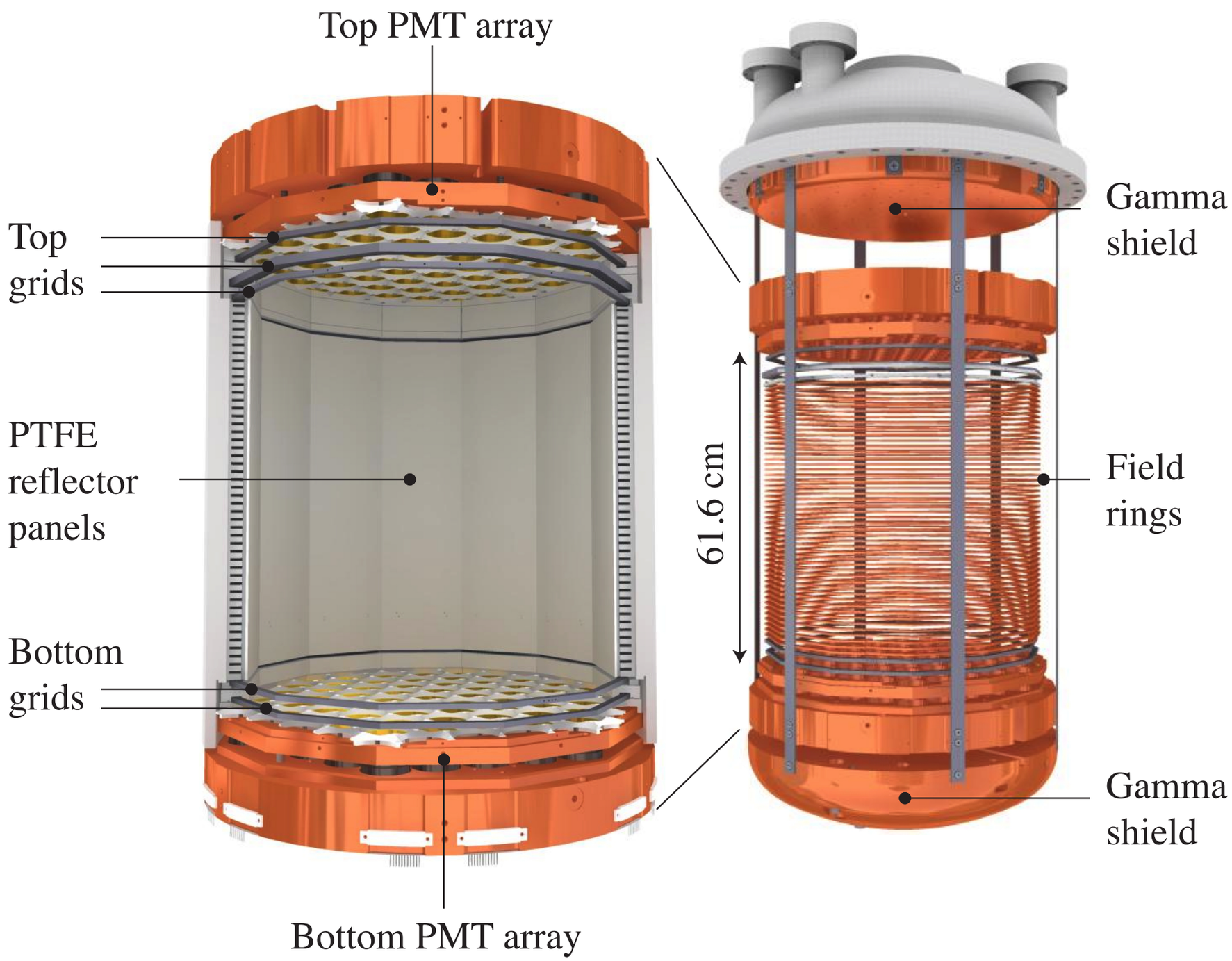


Constantly circulate and purify Xe in gas phase

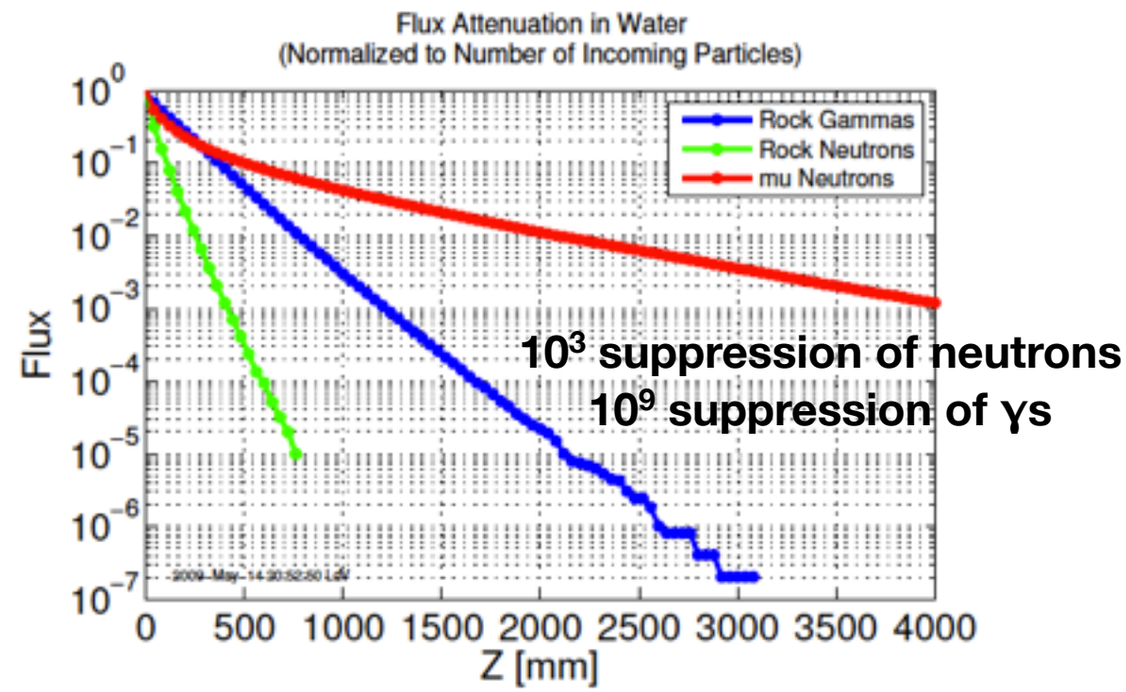


Hamamatsu R8778, 12 stage 2.2” PMTs (61 top/61 bottom)

LUX Inner Detector

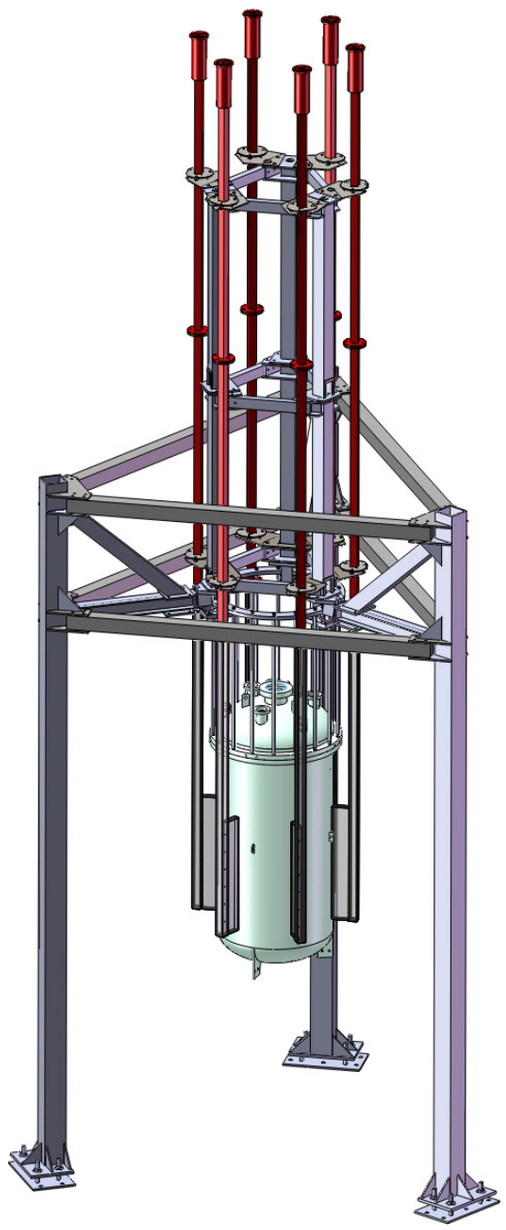


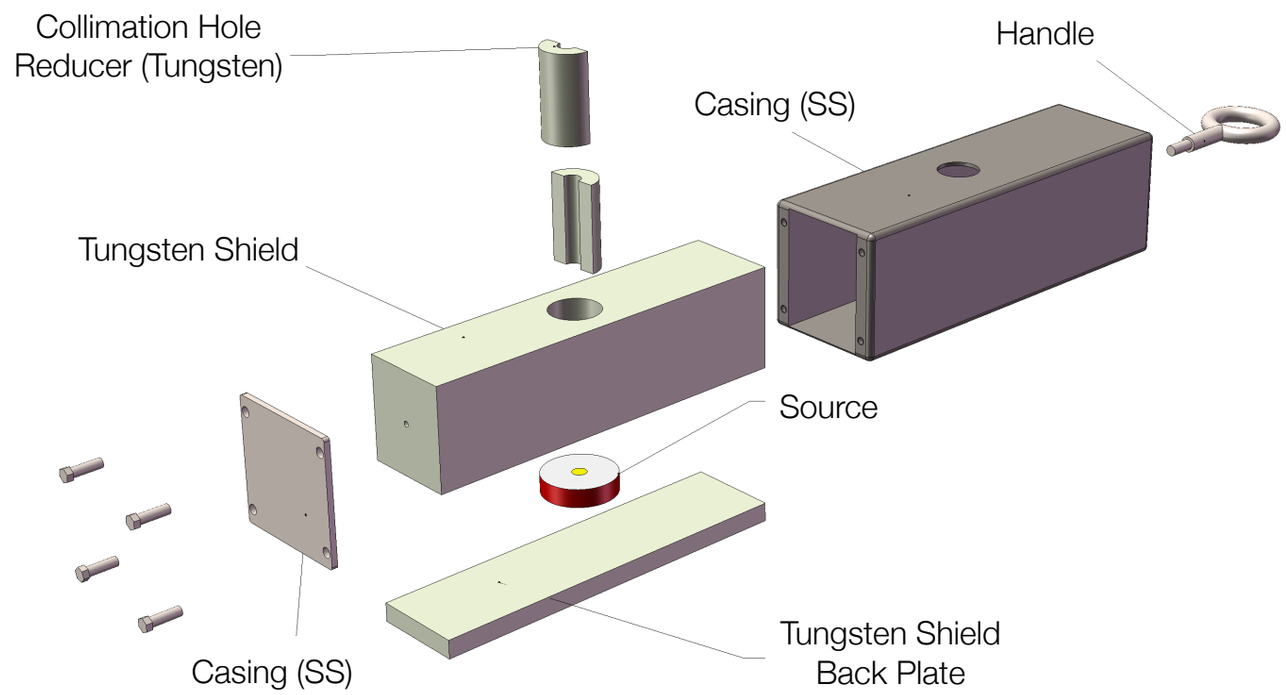
LUX Water Shield



Instrumented with 20 Hamamatsu R7081 10" diameter PMTs for veto of coincident NR candidates

Detector calibration





External sources:

^{241}AmBe, ^{137}Cs, D-D neutron generator

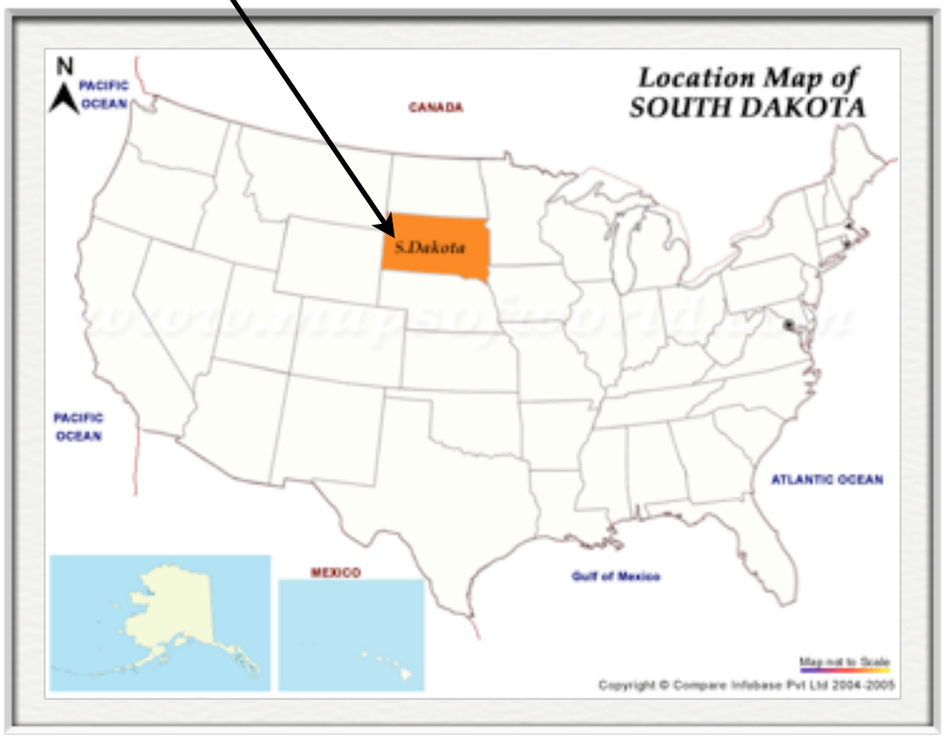
Internal sources:

^{83m}Kr, ^{3}H

Due to self-shielding of LXe, internal sources preferable

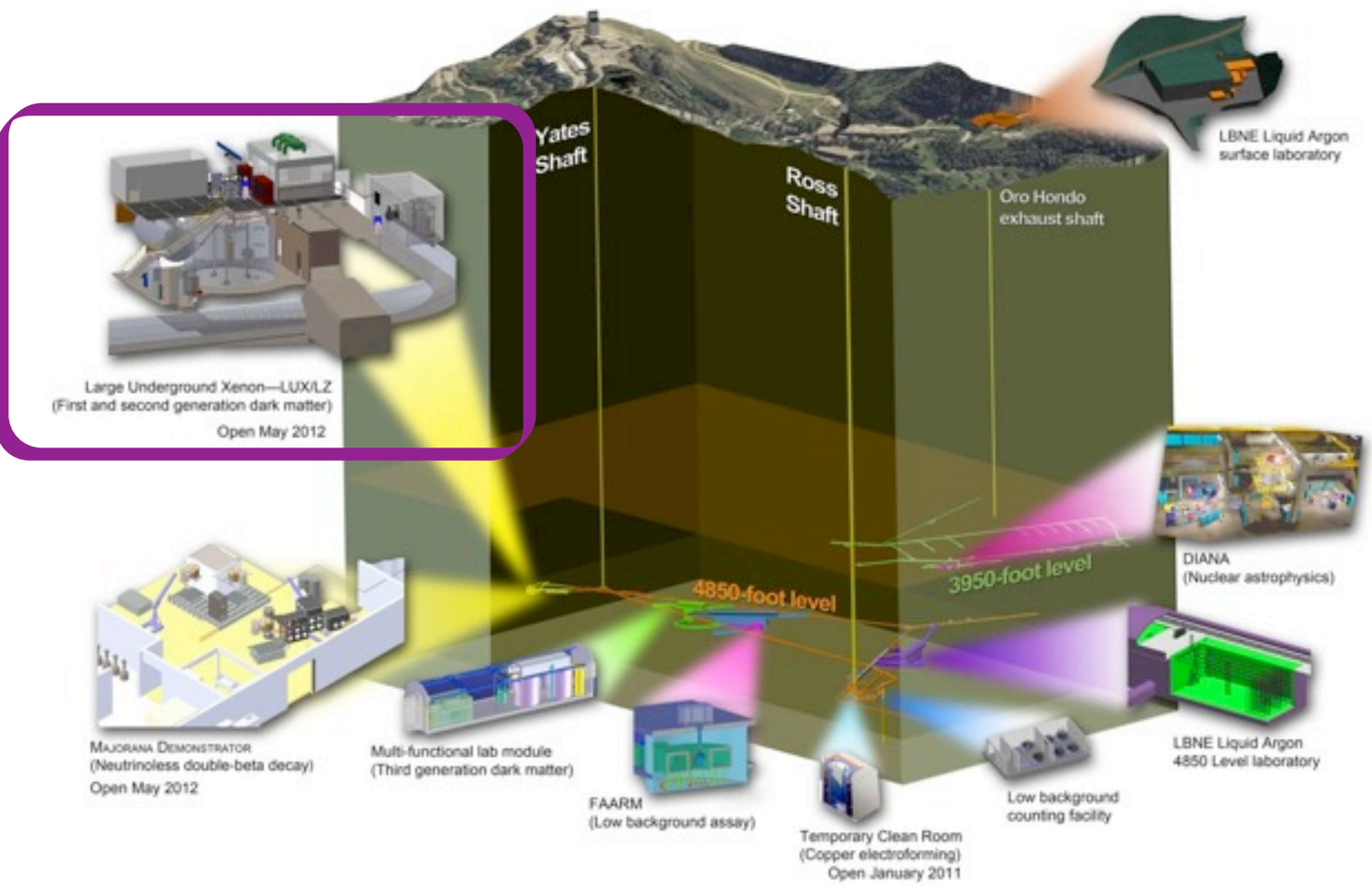
Sanford Underground Research Facility (SURF)

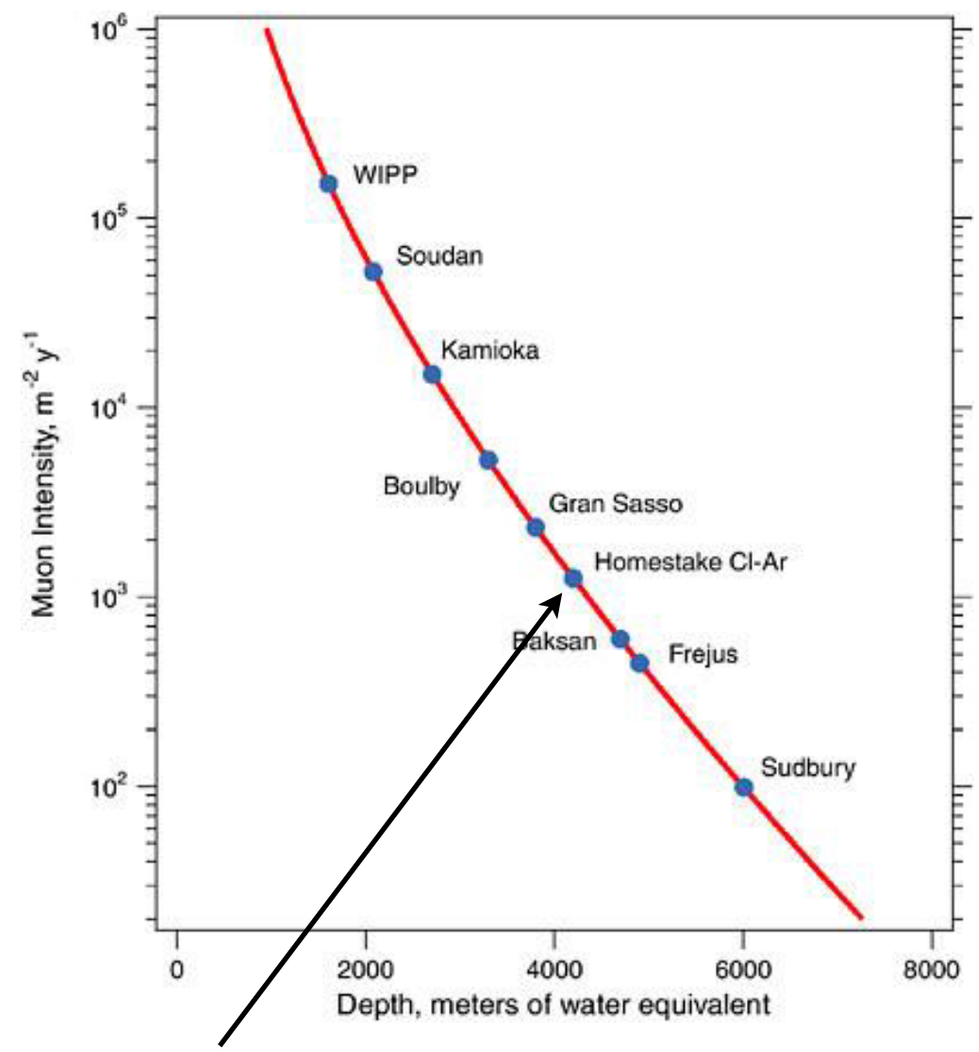
Lead, SD, located in Black Hills



Former Homestake gold mine - repurposed as a “science mine”

LUX at SURF

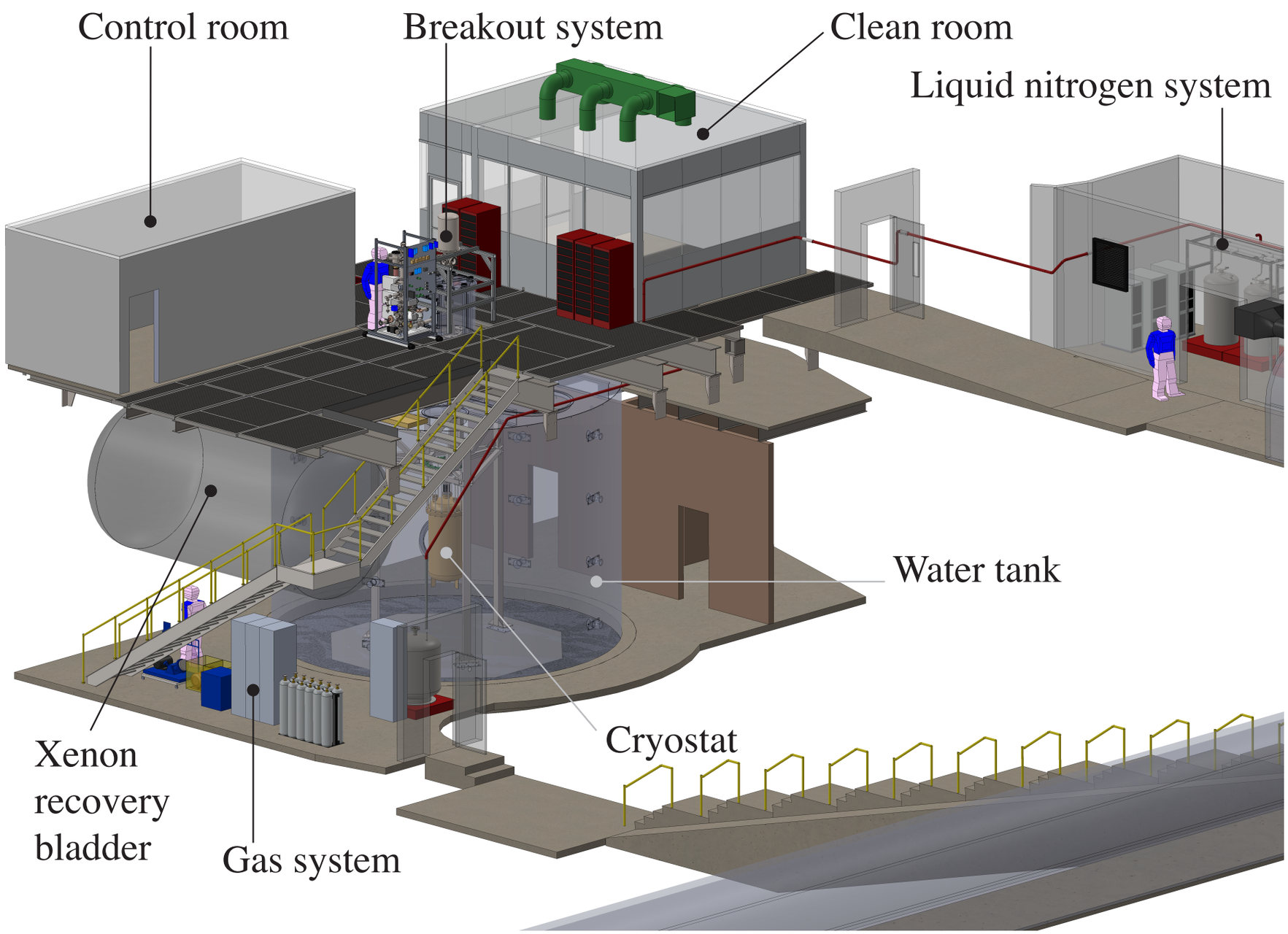




Muon flux at 4850' level reduced by 10^7 relative to the surface

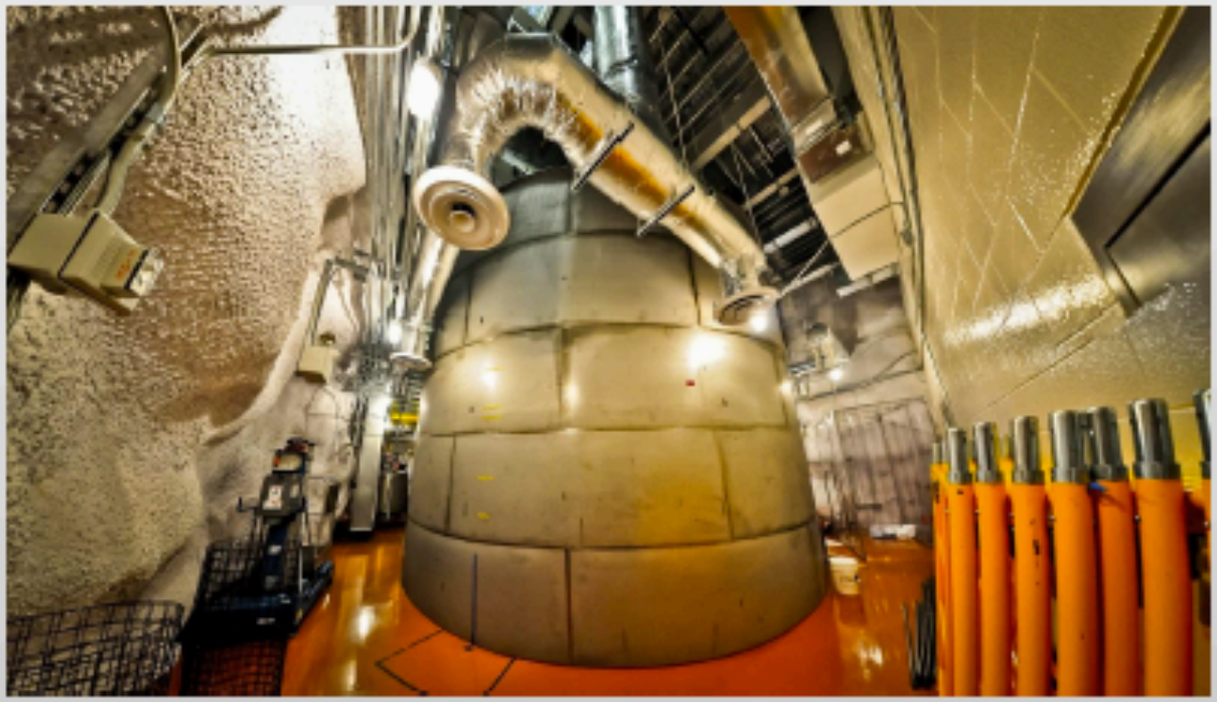
$55.2\ m^{-2}s^{-1} \rightarrow 1\times10^{-5}\ m^{-2}s^{-1}$

LUX in the Davis Campus



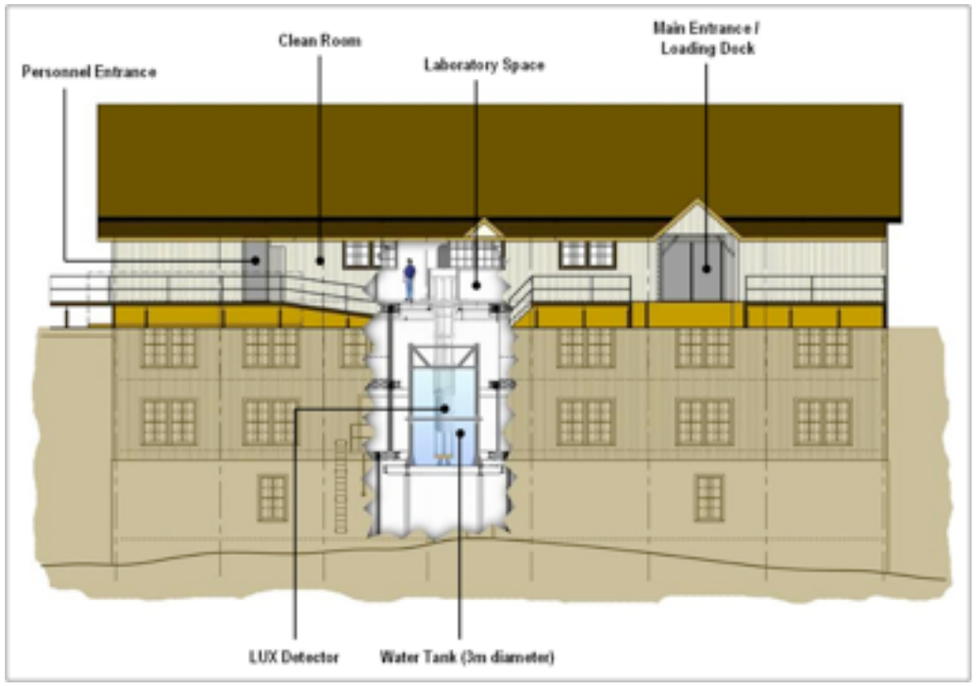
Detector deployment underground

Detector transported underground July 11-12, 2012, deployed in autumn of 2012

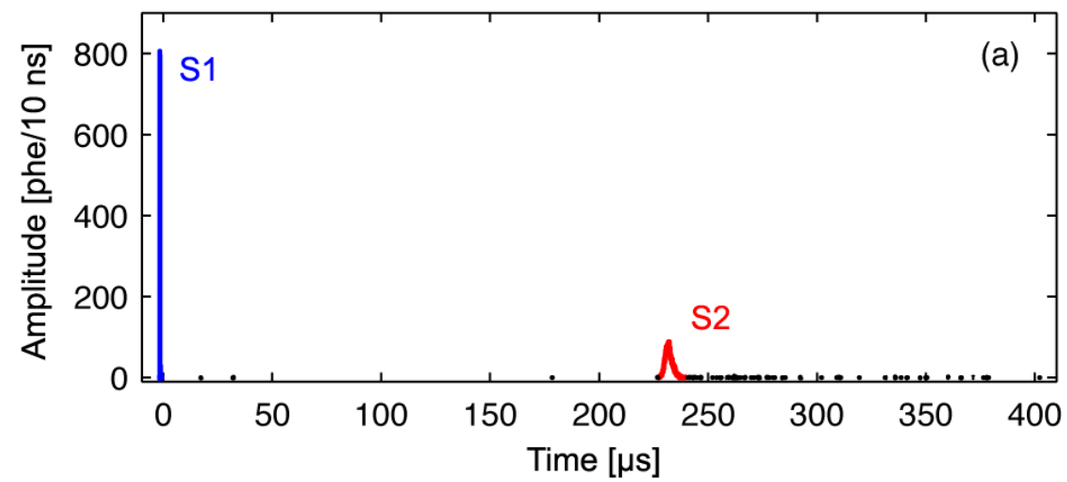


Current Experimental Results

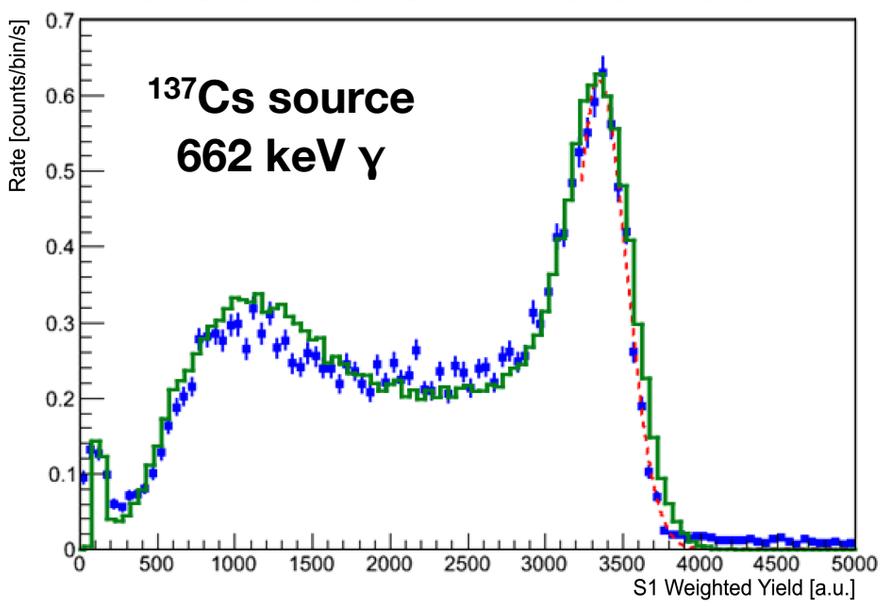
Surface Commissioning



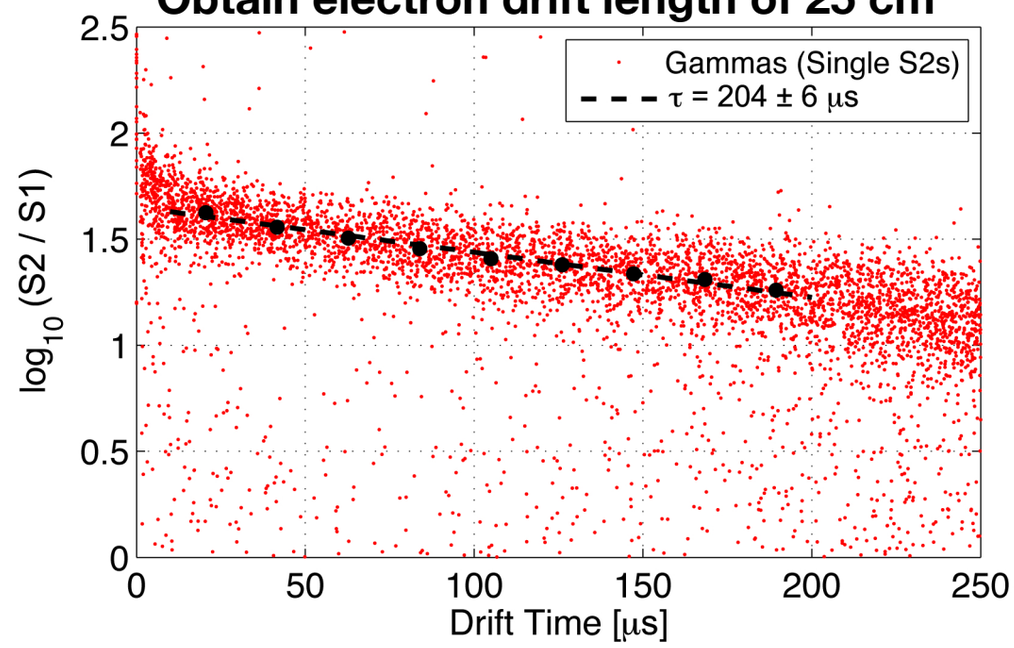
Above ground operation Dec 2011 - Feb 2012



Tune simulation to match data



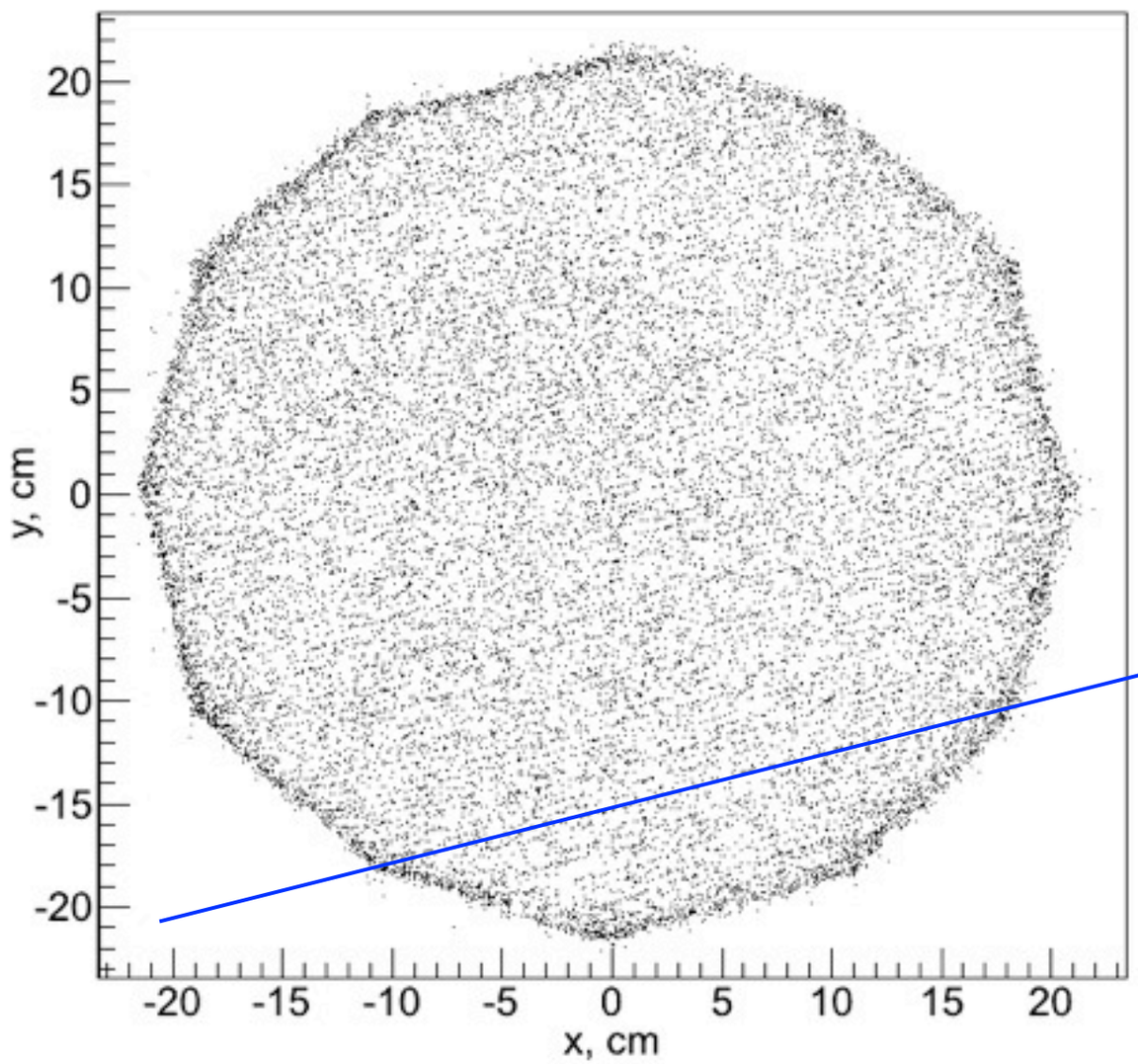
Obtain electron drift length of 25 cm

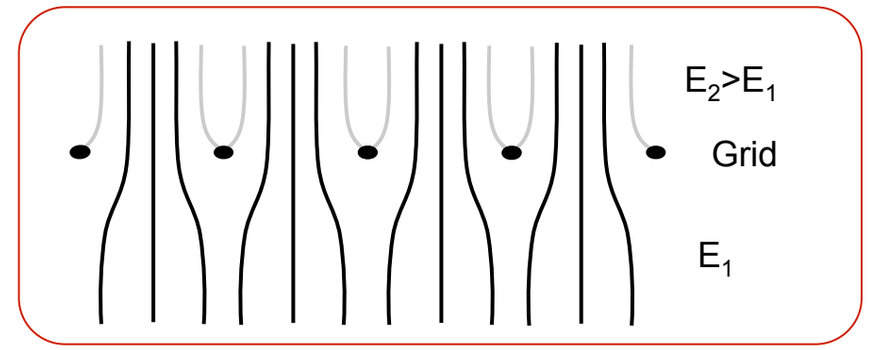


Astropart. Phys. 45 (2013) pp 34-43

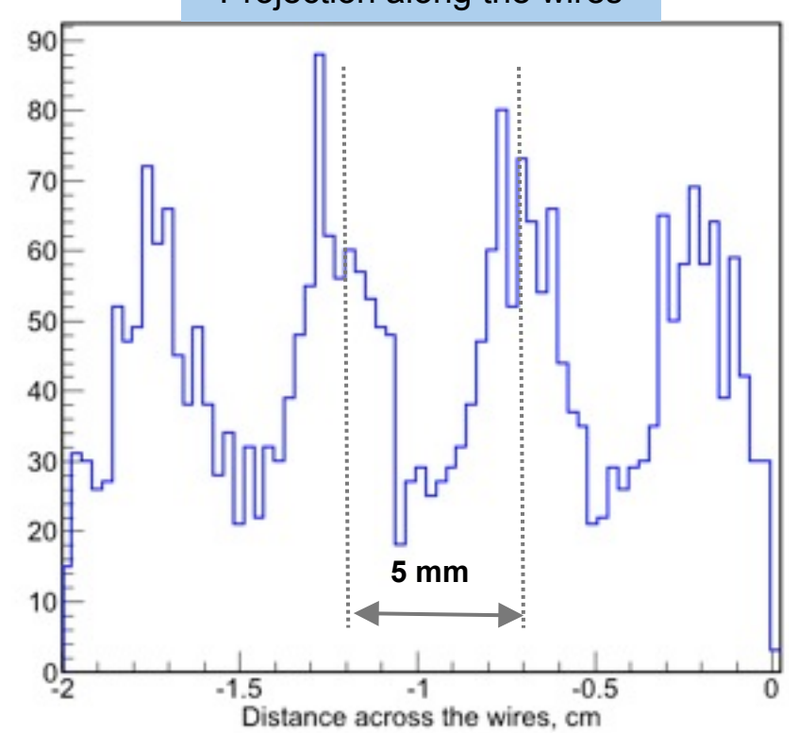
Demonstrate position reconstruction

Estimate resolution of ~7 mm
for high-energy events



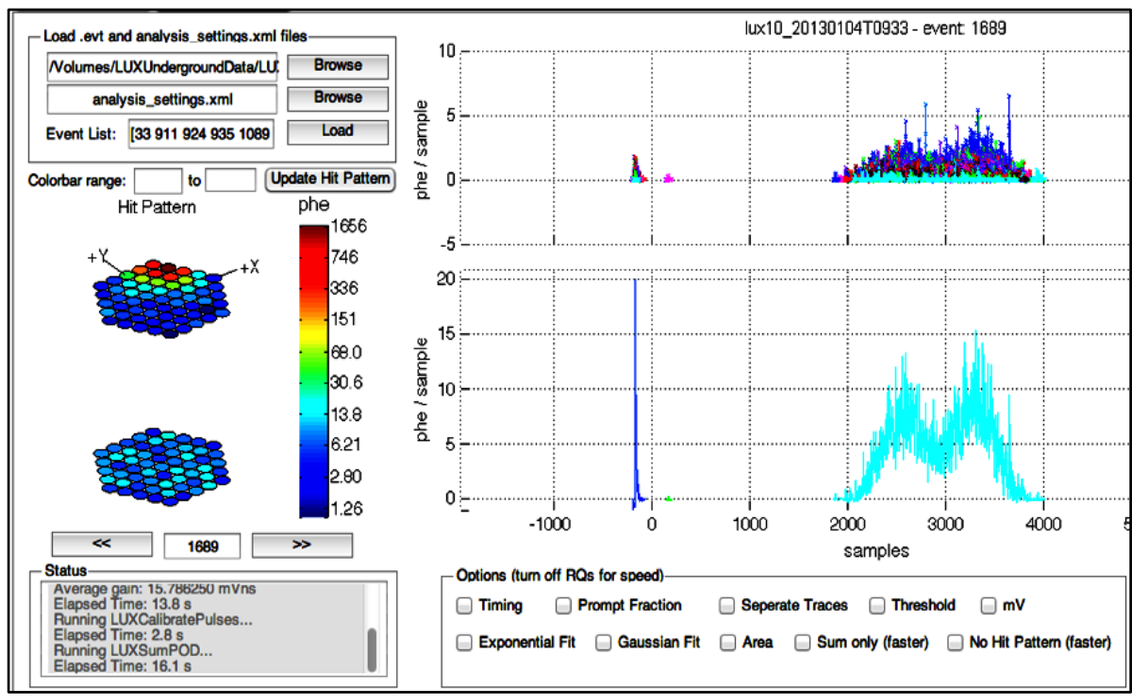


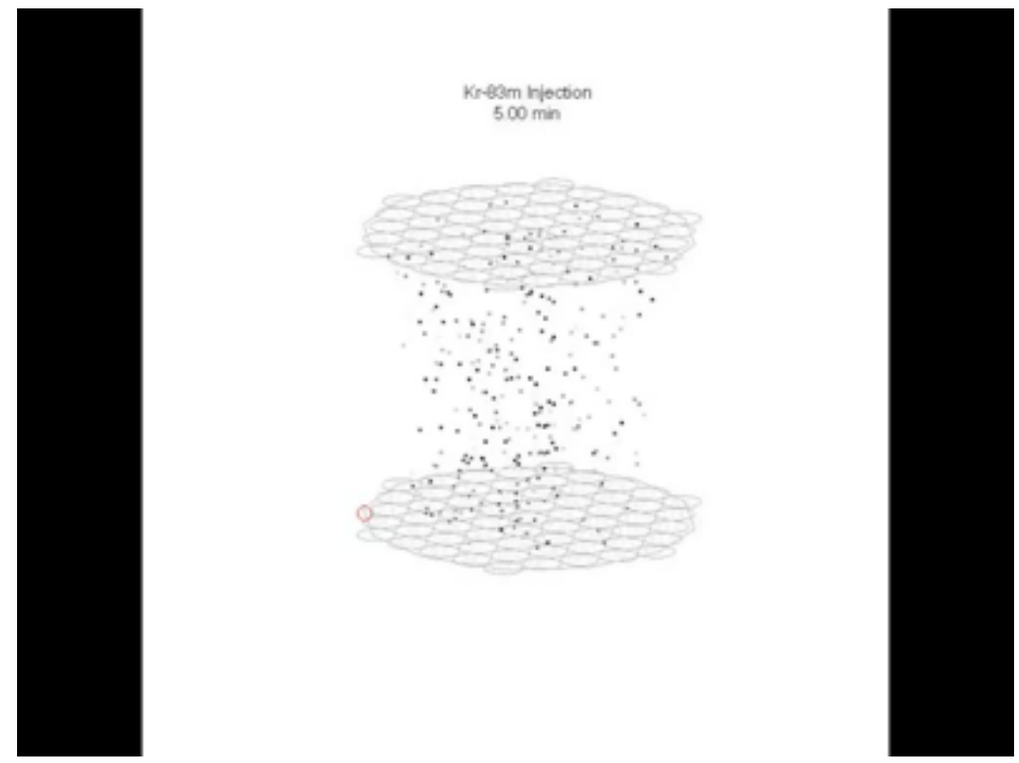
Projection along the wires



Underground operation since January, 2013

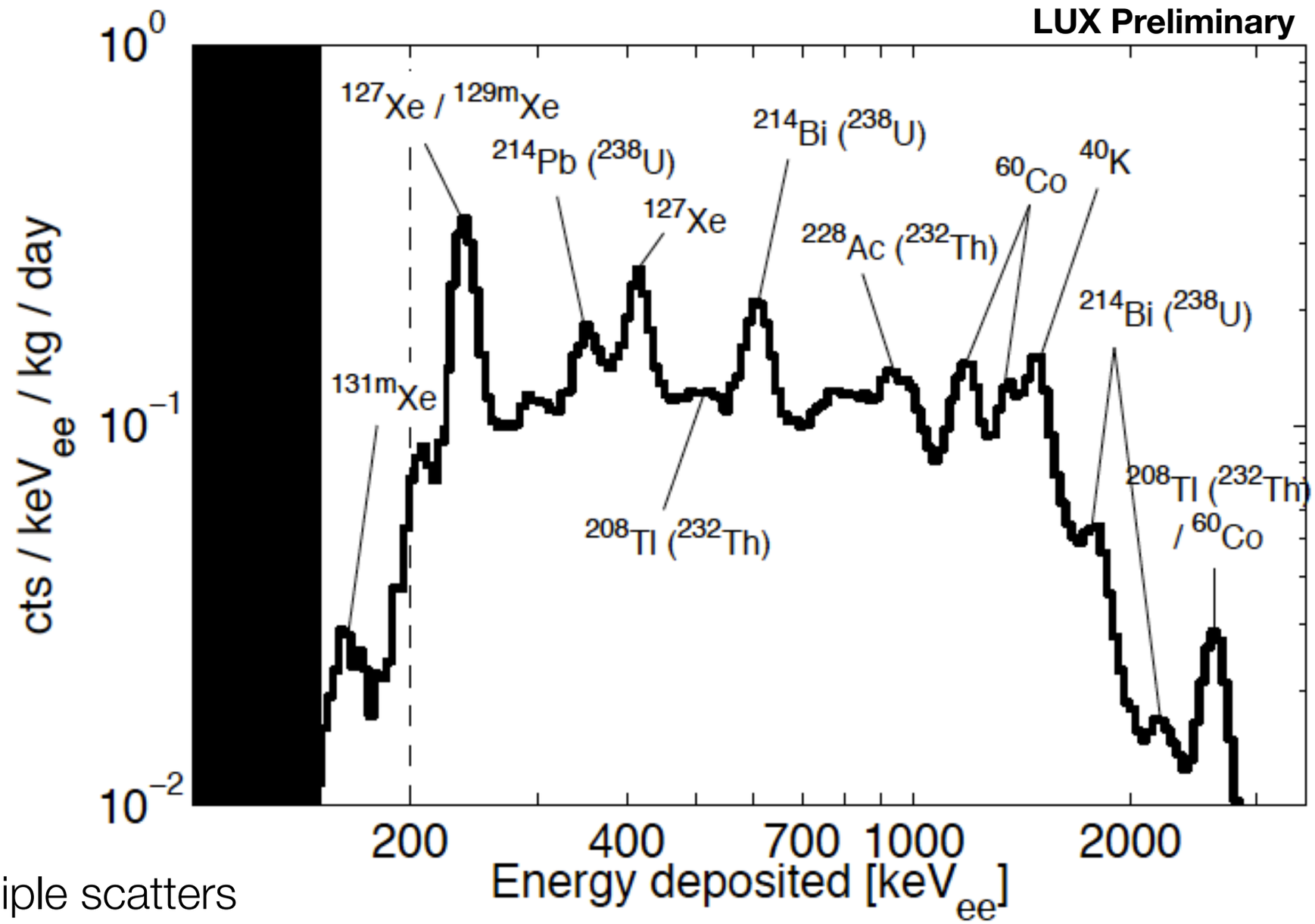
^{83m}Kr gas events injected
into gas circulation line,
1.8 hr half life





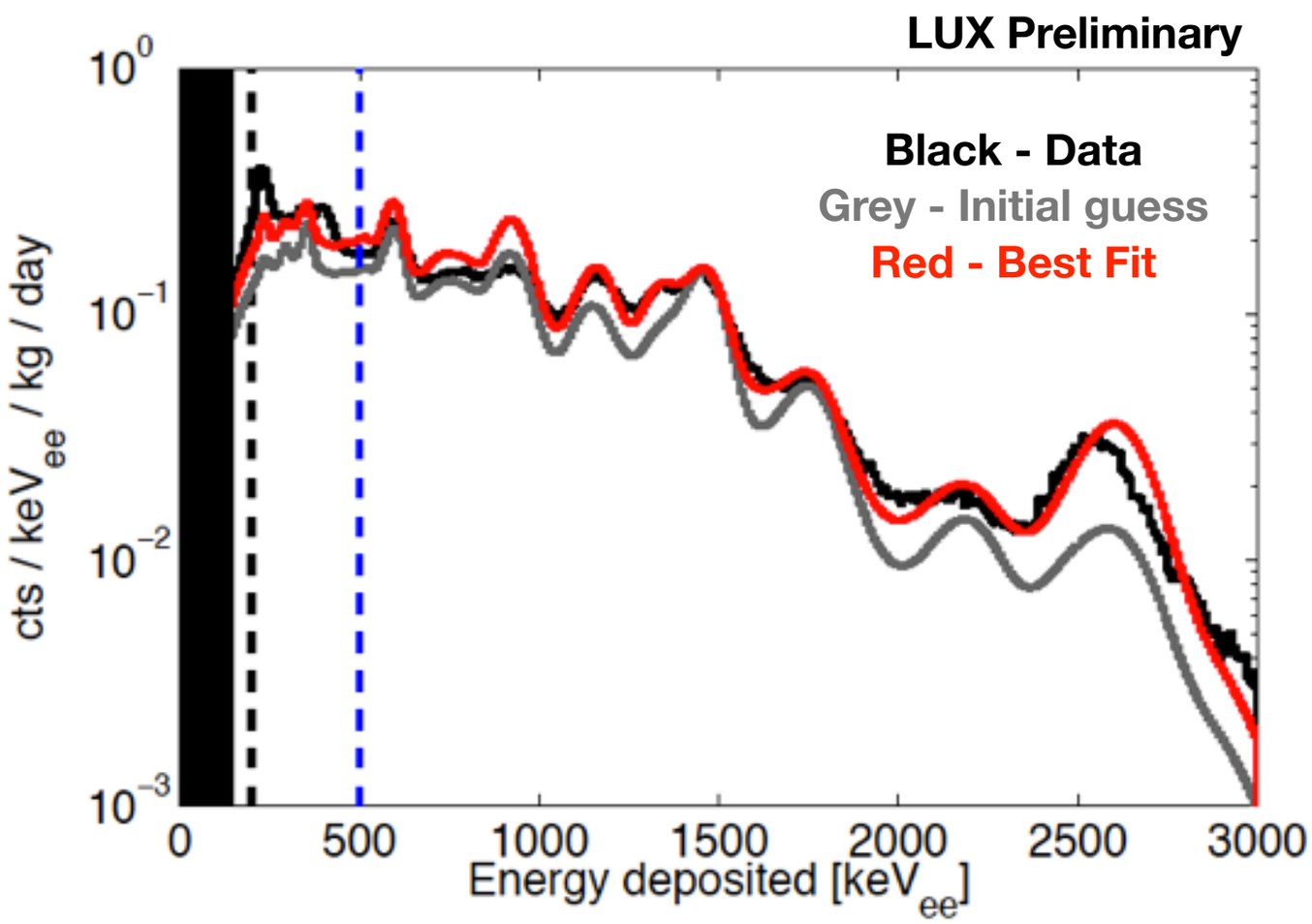
Backgrounds in underground data

See poster by D. Malling for details!



single+multiple scatters
r < 21 cm
13 cm < z < 46.5 cm

Tune simulation to high-energy backgrounds

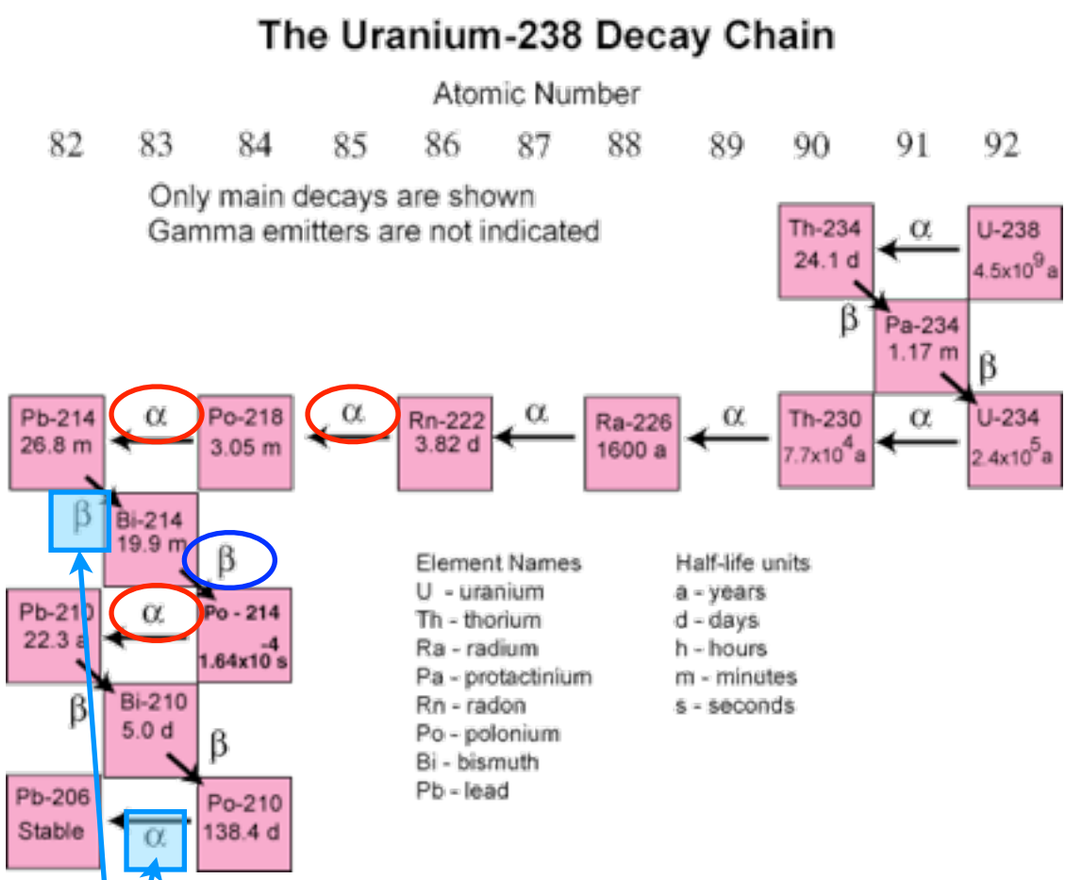


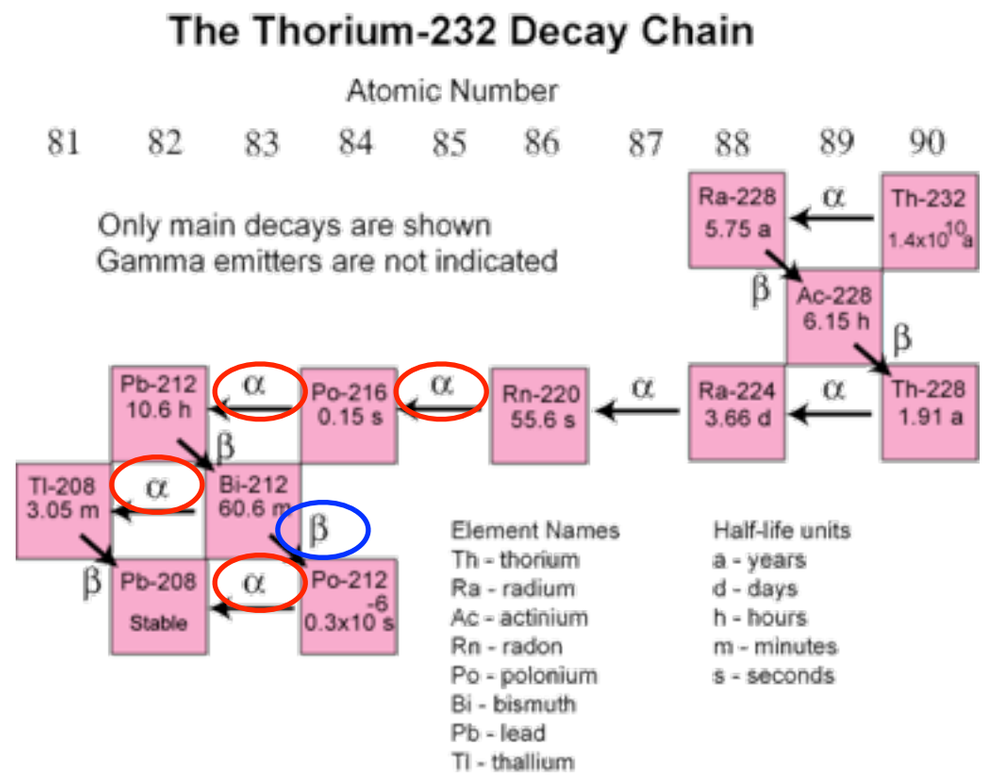
No radial selection
12 cm < z < 47.5 cm

Region	Isotope	Initial Guess [Bq]	Best Fit [Bq]
Top	^{238}U	0.58	0.62
	^{232}Th	0.16	0.23
	^{40}K	4.0	2.7
	^{60}Co	0.16	0.22
Bottom	^{238}U	0.58	0.87
	^{232}Th	0.16	0.25
	^{40}K	4.0	3.8
	^{60}Co	0.16	0.30
Side	^{238}U	0.78	0.22
	^{232}Th	0.33	1.5
	^{40}K	1.4	2.4
	^{60}Co	–	0.36

Predicted backgrounds from SOLO screening of PMTs (top/bottom), superinsulation, and plastic thermal insulation (sides)

Radon-related backgrounds



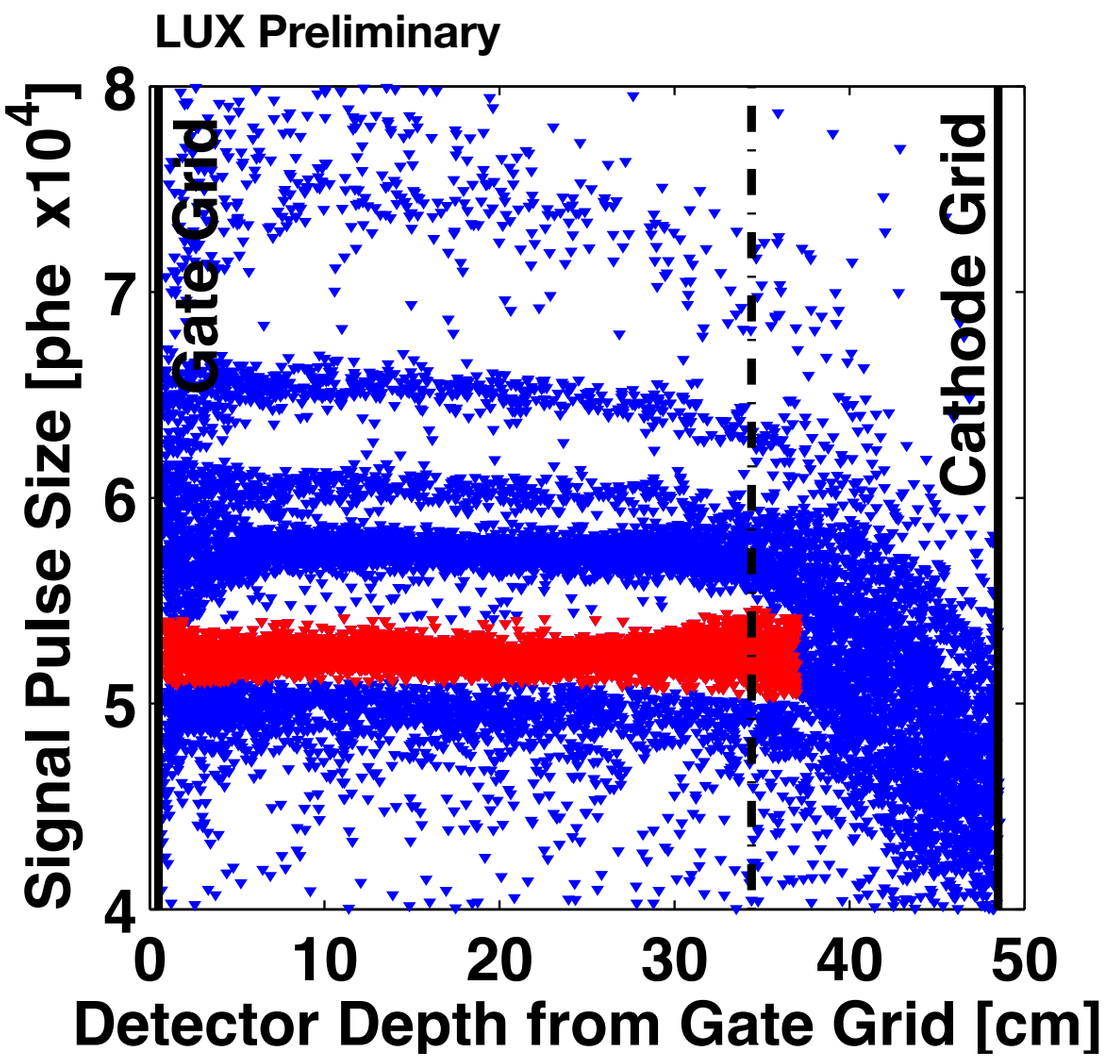


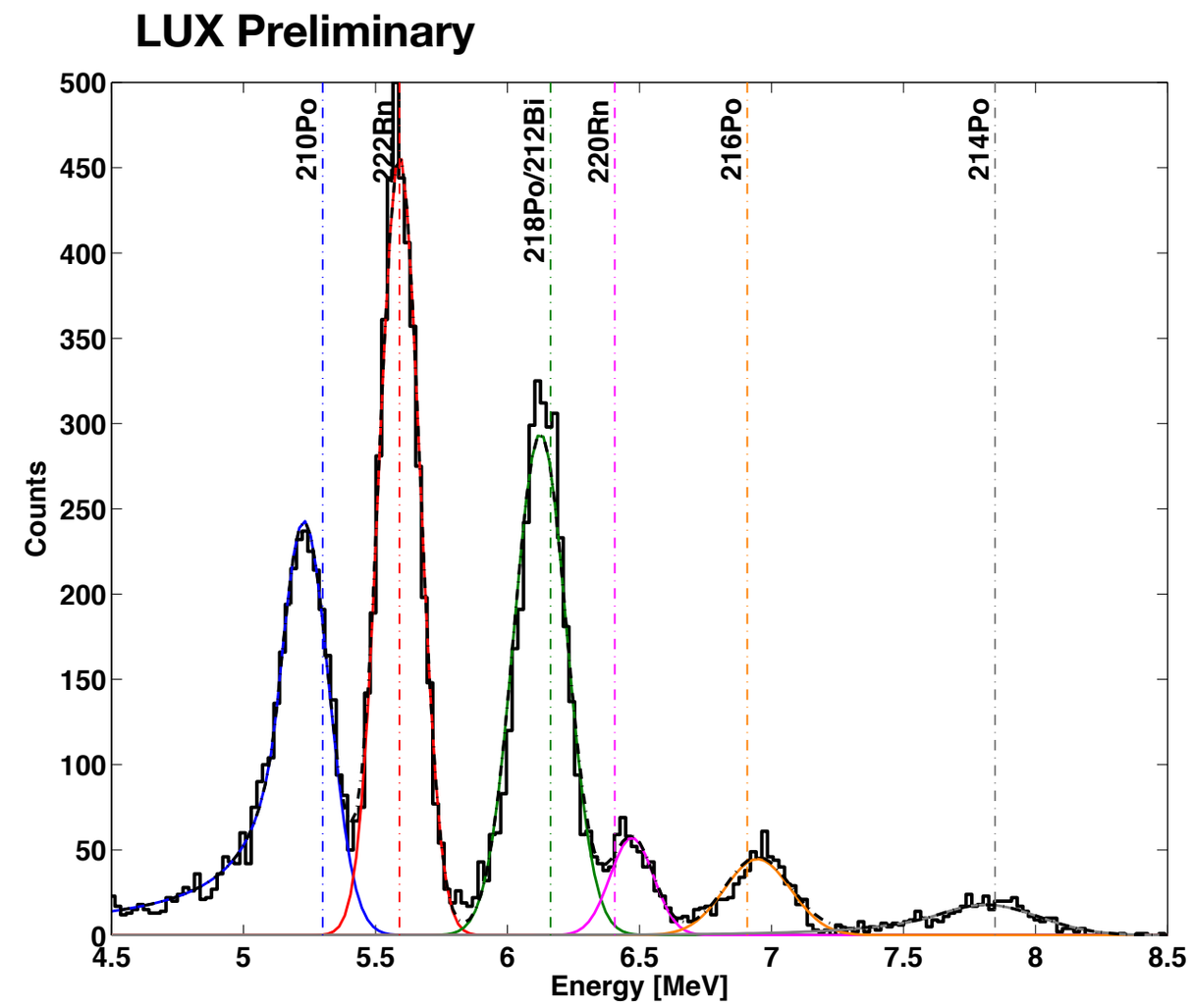
Can easily pick out α recoils in data due to high light to charge ratio, β can be used to tag Bi-Po coincident decays

Potential backgrounds in DM search region

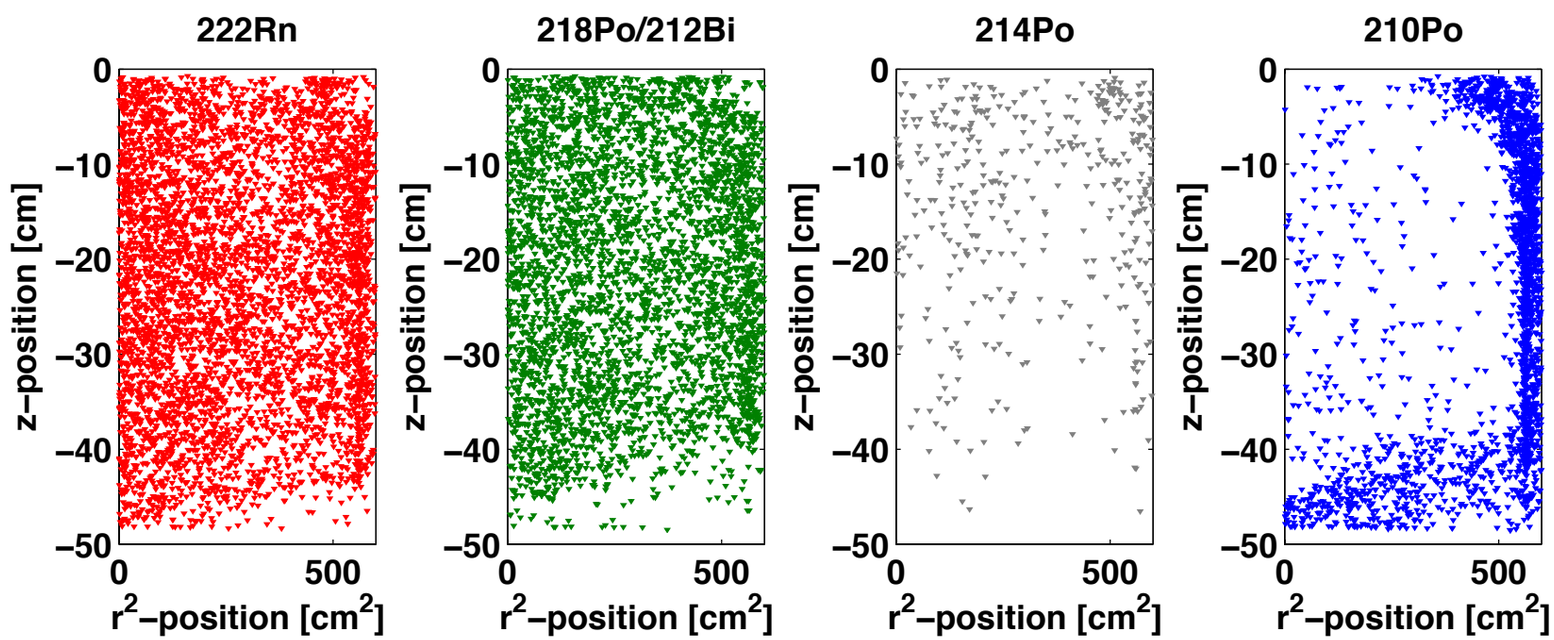
Estimating Rn-related backgrounds in data

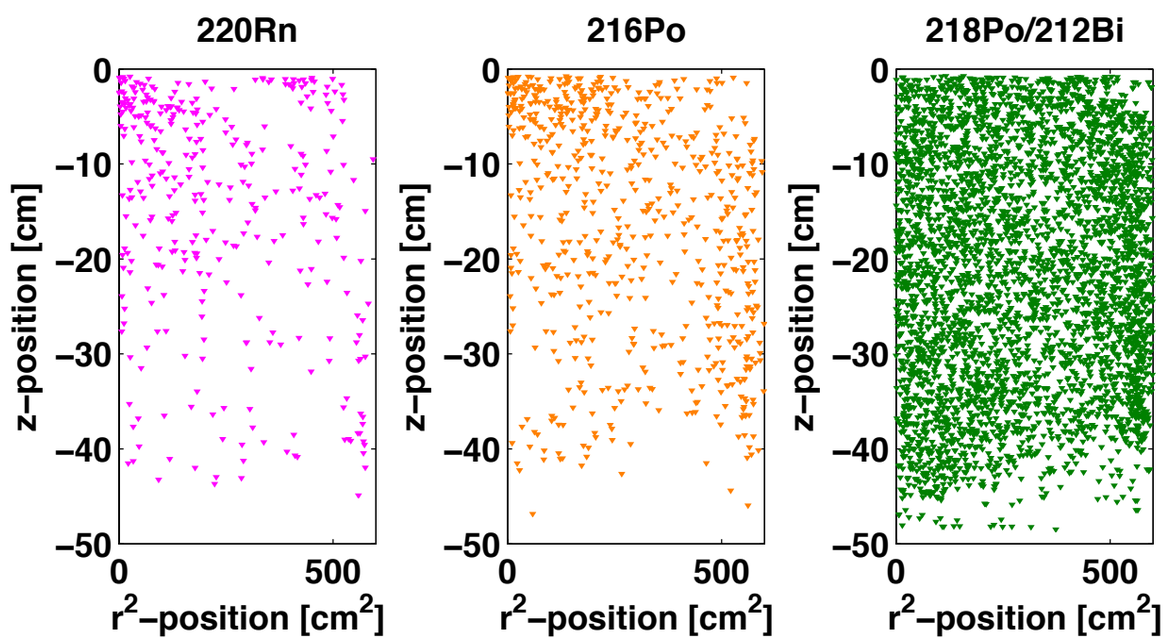
See poster by A. Bradley for details!





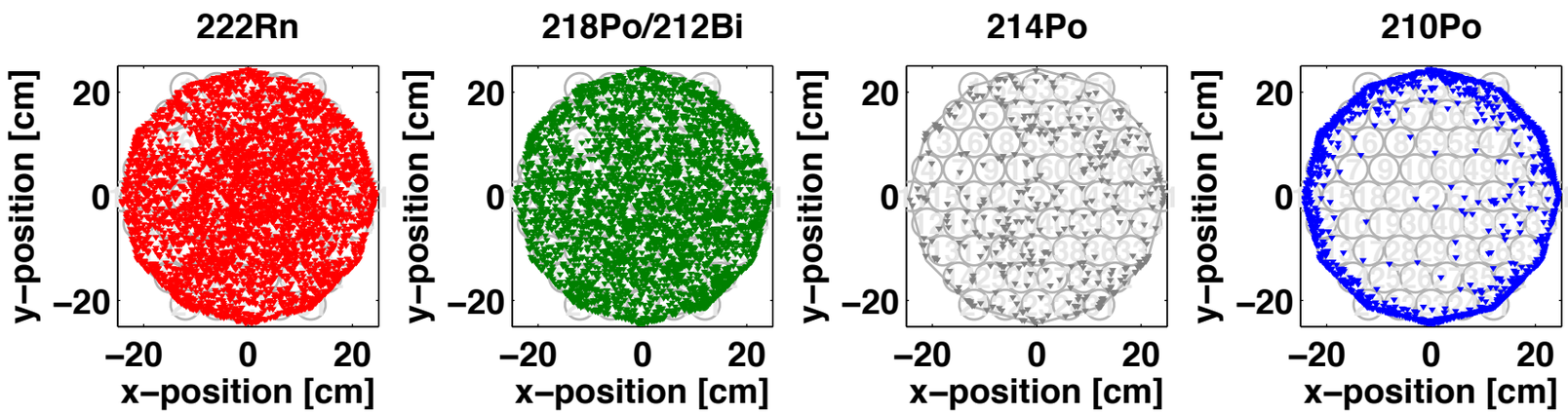
Where are the Rn daughters located?



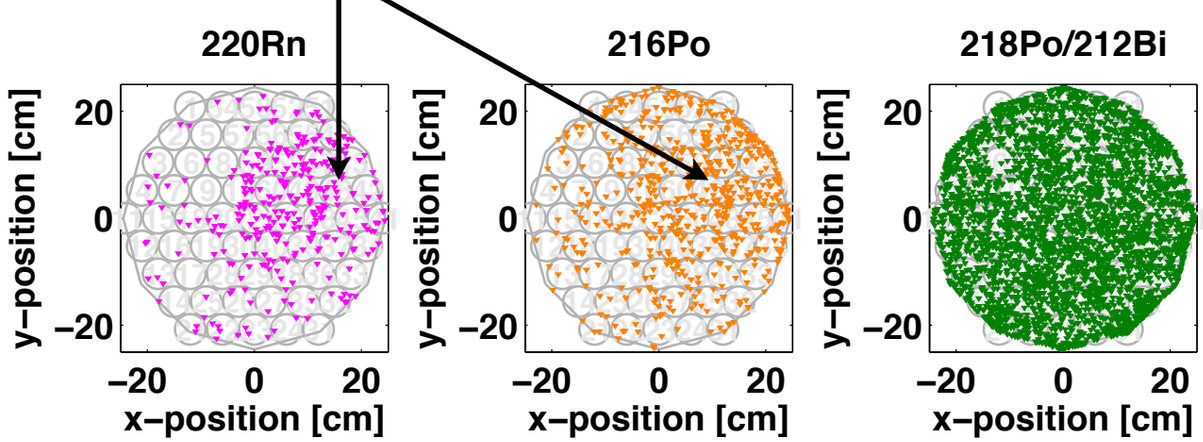


See radon progeny distributed throughout detector, except ^{210}Po which is expected to occur on surfaces due to plate-out of ^{210}Pb

Top-down view of Rn progeny



See x-y localization of thoron decays



Measured rates of α recoils from Rn chain

LUX Preliminary

Decay Chain	Isotope	Half-life	Event Rate (mHz)	General Position
^{238}U	^{222}Rn	3.82 dy	$18.6 \pm 0.2_{stat} \pm 4.2_{sys}$	Uniform throughout bulk
	^{218}Po	3.05 min	$15.7 \pm 0.2_{stat} \pm 3.5_{sys}$	Uniform throughout bulk
	^{214}Po	162.30 μs	$4.0 \pm 0.1_{stat} \pm 0.6_{sys}$†	Sparse throughout bulk
	^{210}Po	138.38 dy	> 21.8* > 10.4*	Walls Cathode
^{232}Th	^{220}Rn	55.80 sec	$2.5 \pm 0.1_{stat} \pm 0.7_{sys}$	Quadrant I, sparse throughout bulk
	^{216}Po	0.15 sec	$3.0 \pm 0.1_{stat} \pm 0.9_{sys}$	Quadrant I, sparse throughout bulk
	^{212}Bi	60.54 min	$15.7 \pm 0.2_{stat} \pm 3.5_{sys}$‡	Uniform throughout bulk
	^{212}Po	0.30 μs	not measured	not observed

† Adjusted for a 52% event reconstruction efficiency from measured value.
* These populations are suppressed due to S2 loss.
‡ Undifferentiated from ^{218}Po rate.

Observe ~20 mHz ^{222}Rn rate, approximately stable during underground operation
Also observe 3 mHz ^{220}Rn rate ⇒ ^{232}Th contamination in detector

^{210}Po rate reflects ^{210}Pb plate-out on surfaces prior to underground deployment

Implications

LUX Preliminary

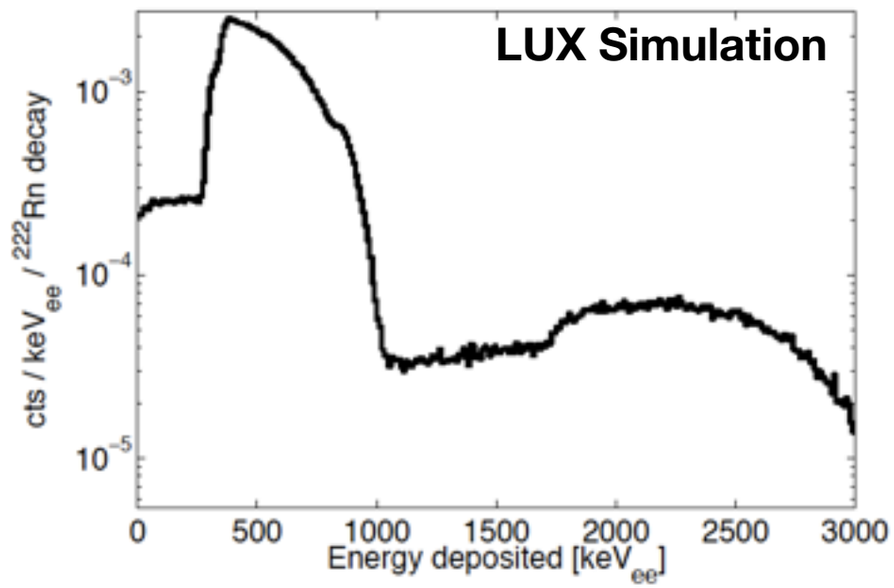
Background	Rate	Comparison/Context
$F(\alpha, n)$ from ^{210}Po α on PTFE	21.8 mHz = 0.017 n/day	PMT neutrons: 1.2 n/day all tubes
^{206}Pb 102 keV recoils	32.2 mHz	Fiducialization removes these
$\Gamma_{^{218}Po_\alpha} > \Gamma_{^{214}Pb_\beta} > \Gamma_{^{214}Po_\alpha}$ ^{214}Pb untagged β 260 kg total active region	0.11-0.44 mDRU$_{ee}$	PMT ER BG: 0.5 mDRU$_{ee}$ 100 kg unoptimized fiducial [D. Malling APS 2013]

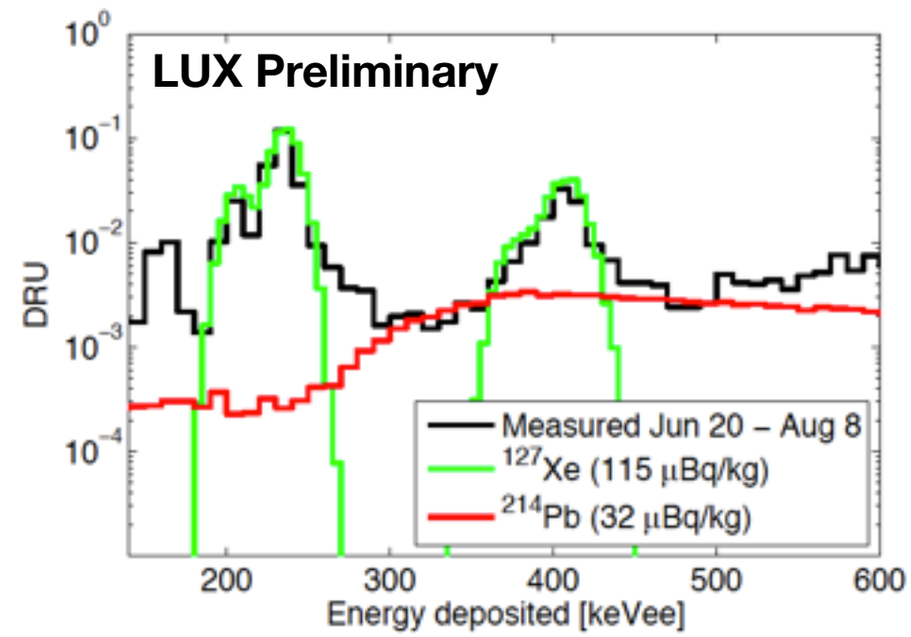
Range bounded by measured ^{218}Po and ^{214}Po α recoil rates

See approximately steady rate of radon progeny during underground running, the sources of which are under investigation. However,

contributions to our WIMP search background are within previous background estimations.

Independent check of ^{214}Pb background rate

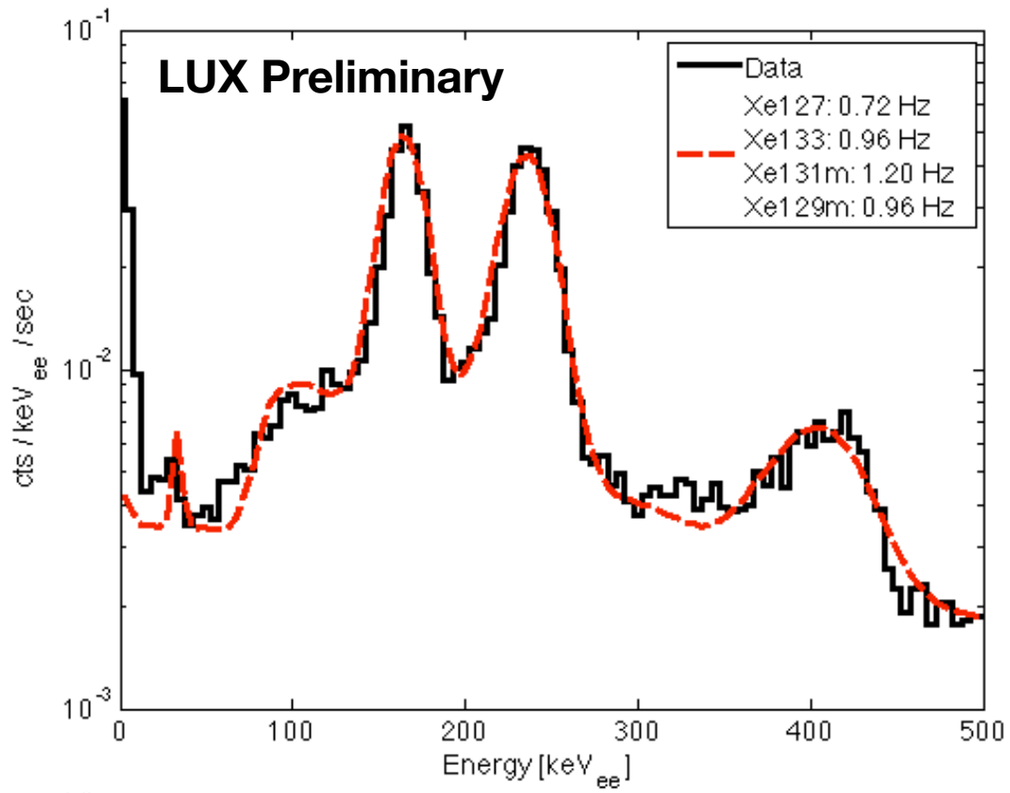




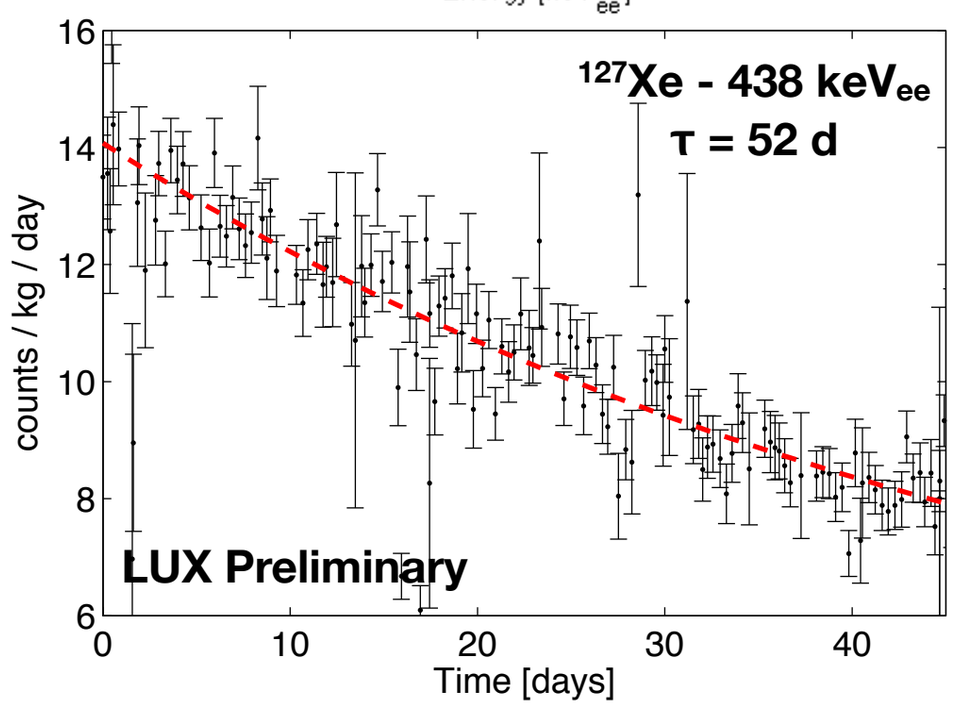
Estimate rate of ^{214}Pb β decay directly from energy spectrum

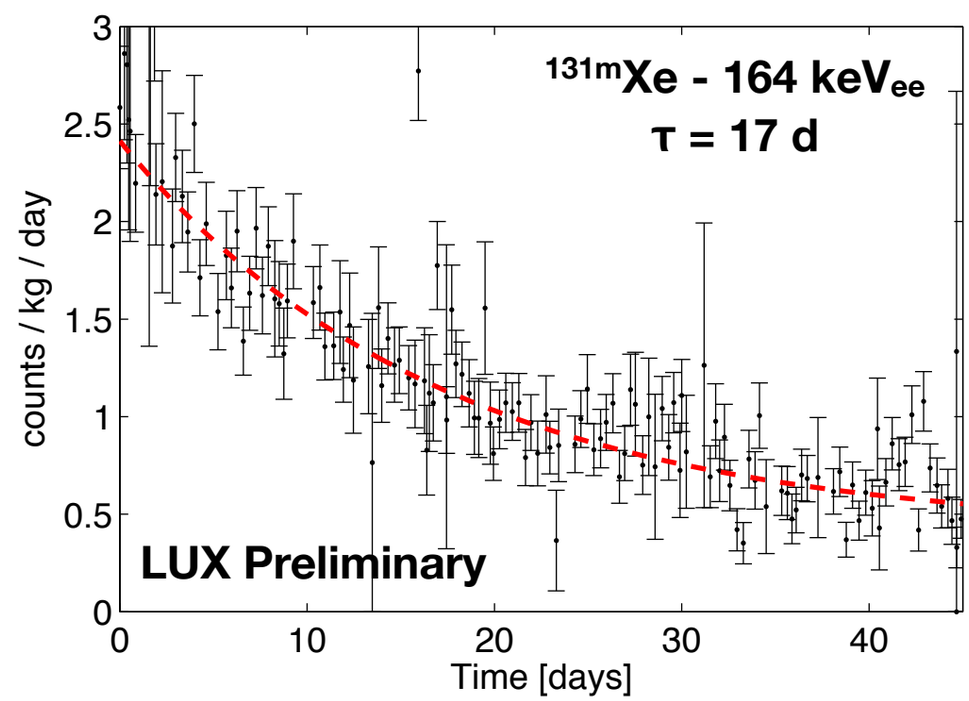
Obtain rate of 8.3 mBq, corresponding to background rate in WIMP search of 0.23 mdru$_{ee}$

Activated Xenon



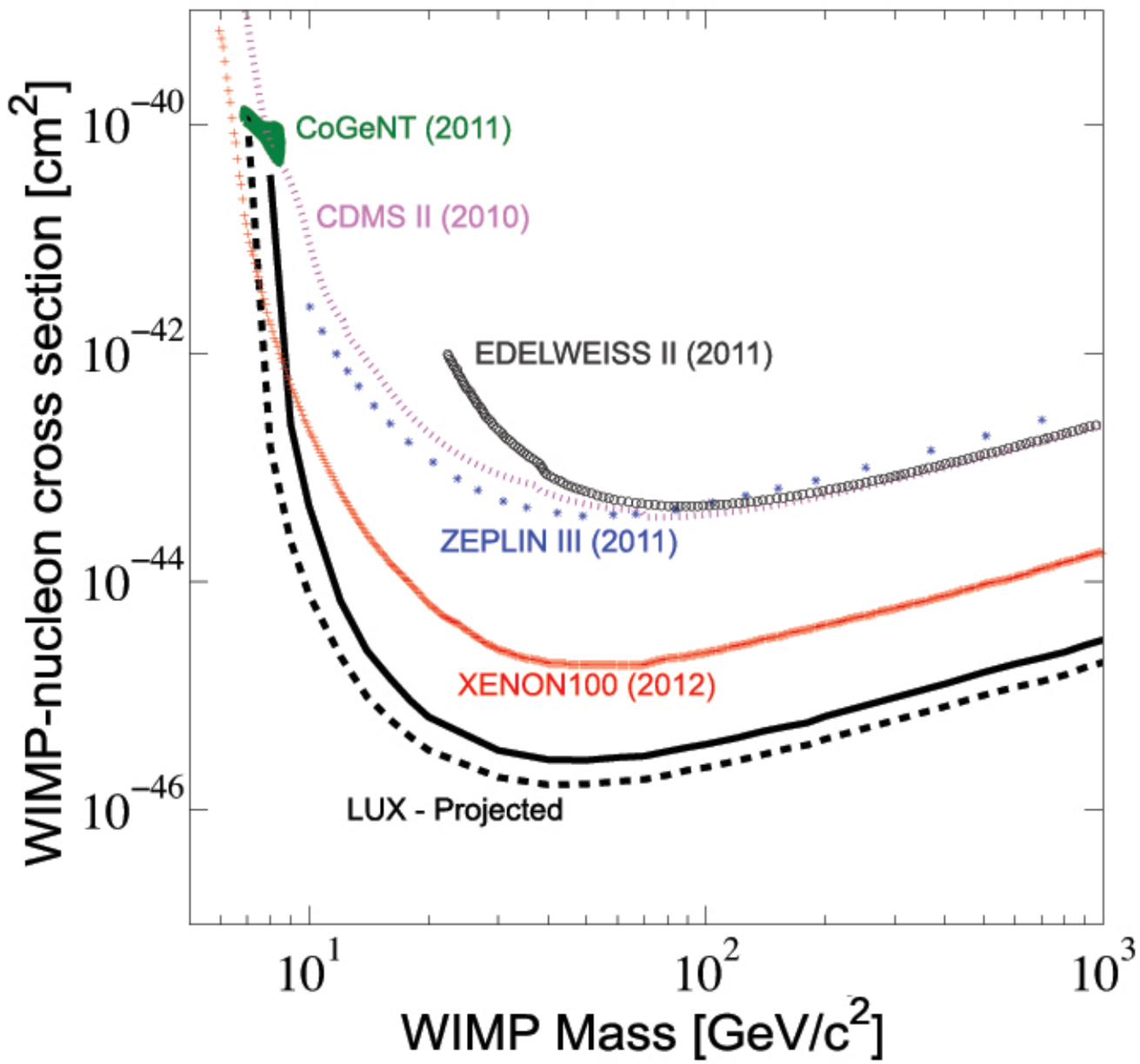
Observe decay of cosmogenically-activated Xe lines during operation underground





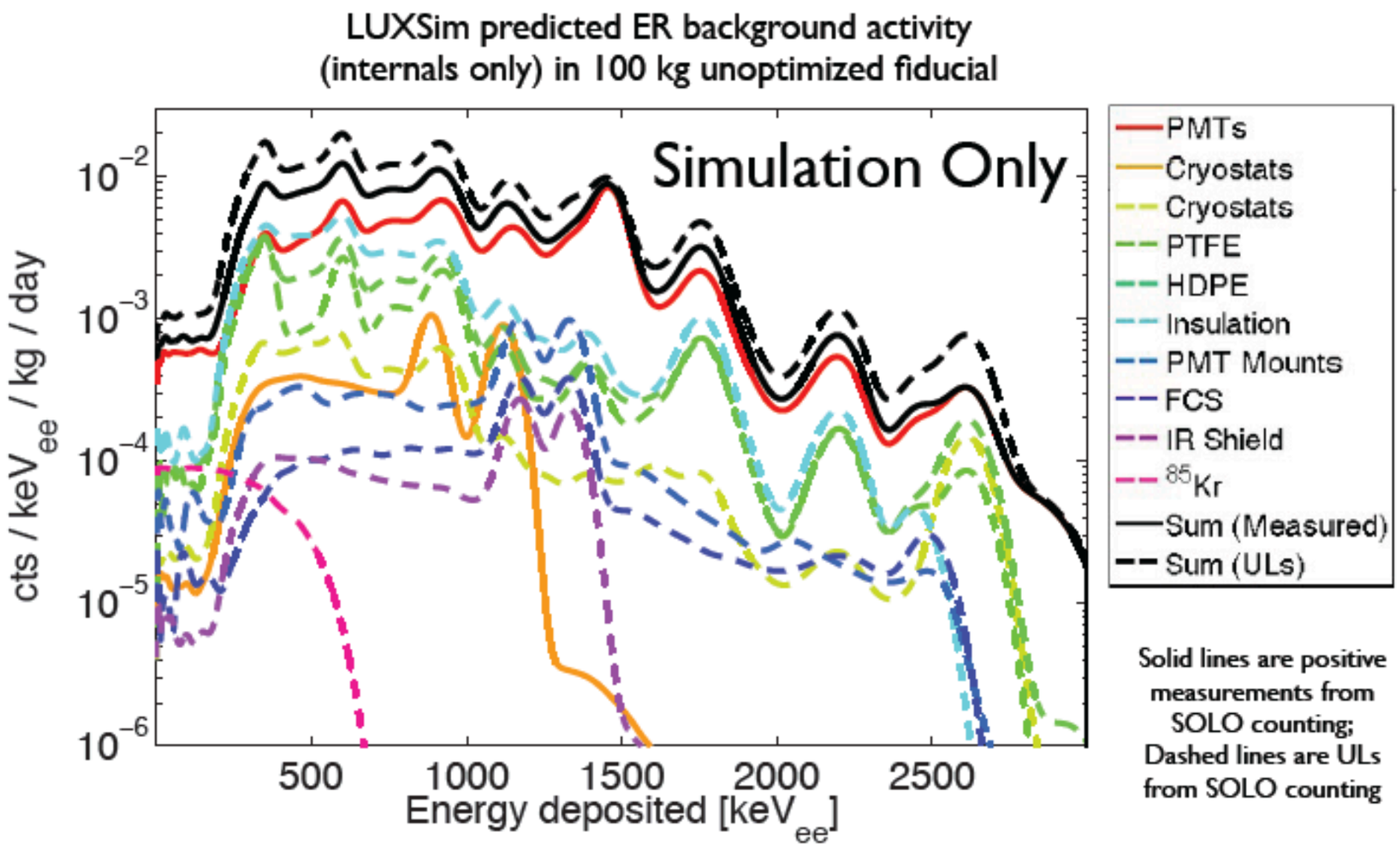
Projections

- LUX has been operating underground since spring 2013
  - Stable detector operation has been achieved!
- Expect first WIMP search result to be announced in autumn 2013!

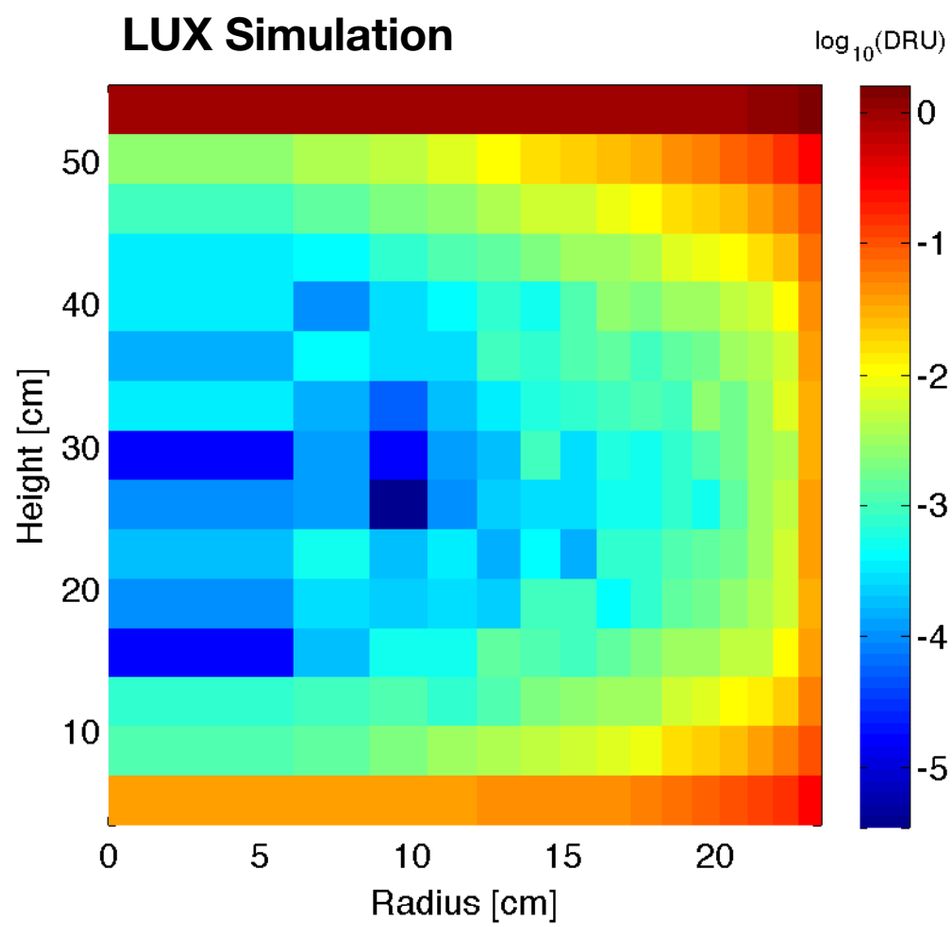


Backup

Contribution of predicted backgrounds



Simulated background distribution in detector

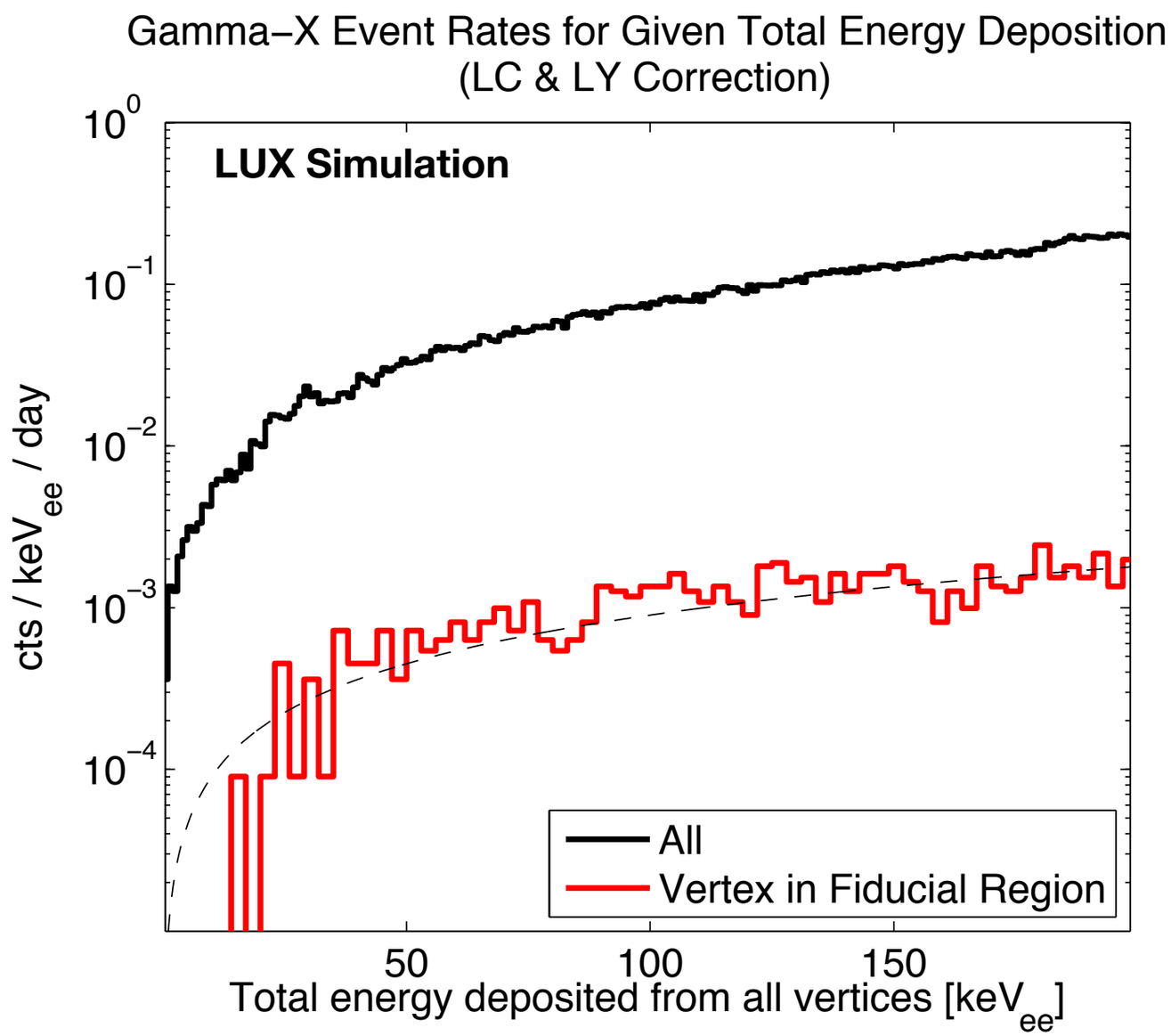


Measured Rn daughter energies

Isotope	Known Energy (MeV)	Measured Energy (MeV)	Decay Chain
^{222}Rn	5.59	5.59 ± 0.08*	^{238}U
^{218}Po	6.16	6.12 ± 0.10	
^{214}Po	7.84	7.80 ± 0.2	
^{210}Po	5.30	5.22 ± 0.09	
^{220}Rn	6.41	6.47 ± 0.09	^{232}Th
^{216}Po	6.91	6.95 ± 0.1	
^{212}Bi	6.21	6.12 ± 0.10	
^{212}Po	8.83	not measured	

*The ^{222}Rn line was used to anchor S1 pulse size-to-energy scaling.

Gamma+X


Gamma−X Event Rates for Given Total Energy Deposition
(LC & LY Correction)
LUX Simulation
cts / keV$_{ee}$ / day
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
50
100
150
Total energy deposited from all vertices [keV$_{ee}$]
All
Vertex in Fiducial Region